Test Report:

Assembly and Structural Loading of Army Research Lab's

High Strength Low Alloy - Vanadium (HSLA - V) Bridge

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April 28, 2010

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **01 APR 2010**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Test Report: Assembly and Structural Loading of Army Research Labs High Strength Low Alloy - Vanadium (HSLA - V) Bridge**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Jim Stankewitz; Eric Osterland**	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA**	8. PERFORMING ORGANIZATION REPORT NUMBER **20770RC**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) **TACOM/TARDEC** 11. SPONSOR/MONITOR'S REPORT NUMBER(S) **20770RC**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**56**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Executive Summary

The Army's Vanadium Technology Program developed a prototype bridge and then approached TARDEC to test and evaluate two-representative sections of bridge. The focus of the effort was on evaluating the assembly time and gathering strain and deflection data under prescribed loads for finite element model (FEM) validation.

The pieces to assemble and join the two sections arrived at TARDEC's Bridge Testing Lab in late January and the bridge was completely assembled inside the lab by 4 men in a cumulative 11 hours over 3 days. The assembly process relied upon an experienced manufacturer's representative (who supervised the entire assembly), 15k forklift, two 30k rolling carts (for positioning the sections for assembly), air compressor, and approximately two dozen commercially available tools and safety items. Comments about the assembly process can be summarized as physically demanding – requiring a relatively long time and fatiguing effort compared to 40 foot of bridge typically assembled by Army Soldiers. Suggestions to improve the assembly time are to reduce the number of fasteners, ship more completely assembled bridge sections and make use of larger forklifts/cranes to lift and join the assembled sections. A section designed along with a launch mechanism and crew choreography is suggested to optimize the time to cross the gap.

The bridge was then positioned, instrumented, and loaded for data gathering. 65 strain gages, 3 thermocouples, and 10 LVDTs were installed to monitor strain and deflection throughout loading. The load cell system was calibrated to measure up to 100,000 lbs load per actuator, and contact pads of 12" x 14" were placed over the deck load positions. The bridge was placed on level supports on top of two 8x8 pieces of plastic reinforced composite timbers centered below the outermost diaphragms. Four loading configurations were used to gather data to later be used to refine a finite element model (FEM) of the assembly. The bridge responded with a maximum deflection of .2" and 1046 ue under 200,000 lbs of load at the mid-span. Local deflections of approximately .5" were seen on the center span outer deck panels while the cylinders pushed with 100,000 # on the center of those panels.

The 40-foot prototype span was shown to be assembled in 44 man-hours, and proved extremely rigid under 200,000 lbs of load at mid-span.

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1. Background

The Vanadium Technology Program is focused on finding applications for Vanadium steels. Vanadium steel can be used to provide structural members for construction and Homeland security applications. Army Research Lab (ARL) is also interested in military applications of high strength low alloy vanadium steel in bridges used for main supply route missions. Due to budget constraints and a desire to limit risks in developing a 200-foot span portable bridge, ARL contracted for the development of a representative 40-foot span of the main girder, splice joint, and decking system. This 40-foot span was the subject of the testing at TARDEC.

2. Purpose and Scope

The first phase of the testing was to assemble the prototype 40-foot span. The purpose of the assembly was to assess the effort required, identify the tools needed, and provide feedback to improve the assembly time. This information could be used in refining later designs.

The following phase of testing was to assess the behavior of the sections under load. The purpose of the load testing was not to provide a bridge Military Load Class rating, but rather to provide data to refine and verify a finite element model used to design the structure. The bridge sections provided were scaled to simulate a portion of a 200-foot span bridge, and the load cases were selected to investigate the behavior of the splice joints and deck plates.

3. Bridge Assembly

3.a. Approach

The bridge arrived fully disassembled – each tub girder on separate semi-trailers with deck plates and side plate support arms stacked on wooden pallets. Fasteners separated by bolt length were supplied on a separate pallet. The tub girders were each unloaded by a 15k fork truck onto rolling pallets for positioning during the assembly. The entire shipment was moved indoors and staged on the 150' x 50' lab floor for quick assembly.

Using the advice of a steel industry representative and assembly drawings from a manufacturer, the assembly began by joining the sections at the splice plates. Fasteners were simply hand tightened to allow later adjustment to align boltholes. Tanker bars (4 foot steel rod with a tapered blunt end at the handle and chisel tip) were used to align holes and plates into position for assembling the fasteners.

Two men lifted each of the twelve support arms to be mounted on the outside of the tub girders while another two men aligned the boltholes and secured fasteners.

The first center deck panel was positioned per the advice of the industry rep to make certain any match-drilled holes in the tub girder would align. Once the forklift had the panel near position, a straight-shank pry bar was inserted thru the holes to hold the panel in position as the fork truck backed away. Tanker bars were used to bring the panel into precise position while bolts were placed thru the panel. Assembly continued as the overlapping deck panels were placed into position and secured with bolts. The nuts and washers were then installed and hand tightened throughout the deck assembly. An air powered impact wrench was then used to secure the side panels to the center panels and tub girder, making sure the deck remained level.

The impact wrench was then used to tighten the remaining nuts. This was followed by tightening the fasteners to 600 lb-ft of torque using a large torque wrench combined with a cheater bar or a torque multiplier and 100 lb-ft torque wrench. Afterward, cross bracing that supported the tub girder during shipment was removed.

3.b. Resources

The following tools, safety protection, and material handling equipment were used during assembly.

```
Tool List
===============
600 ft. lbs. torque wrench
50 ft. lbs. torque wrench
32,000 ft. lbs. torque multiplier
2 tanker bars
White out
1-7/16" 6pt sockets (3/4" drive)
3/4" drive air impact (115 psi)
Flat screwdriver
Rachet strap
Lights
Safety ladders
Working platform
Straight shank prybar
1-5/8" socket 6pt sockets (3/4" drive)
 C-Clamps
1-7/16" combination wrench
Work gloves
Safety glasses
Ear plugs
3/4" to 1" drive adapter

MHE
============
15,000 lbs forklift
6,000 lbs. forklift
5,000 pallet truck
Two 30,000 lbs. 6'x16' caster wheeled carts
```

3.c. Assembly Time

The assembly crew consisted of four men each with military and/or construction experience. All had worked as a team in the past and have a good working relationship.

Assembly began at 12:15p on the day the shipment arrived and ended at 3:00p. The following two days the crew worked in 2-3 hour shifts breaking for lunch and at the end of the day. The total accumulated time for assembly over the three days was 11 hours.

3.d. Observations

It becomes uncomfortably hot inside the tub girder during assembly. This would be considered unbearable at higher solar/air temperatures. The assembly was done indoors at 50F air temperature with radiant heaters 20 feet overhead and required a 20" box fan for circulation inside the girder. When possible the crew worked outside the deck to tighten bolt heads, and it is suggested that a future design consider having the torque of fasteners done from the outside when possible. Working outside the girder the crew still grew fatigued after a couple hours of assembly.

3.e. Suggestions

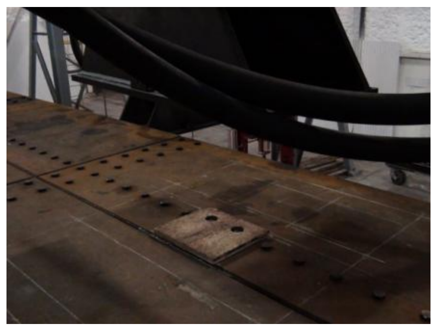
```
Suggested modifications to reduce assembly time*
==================================================
Use powered torque multipliers to torque bolts
Ship more assembled - use 15k lift capacity to reduce number of parts
Reduce on-site bolt-nut assembly / eliminate bolts
Use fine thread bolts to reduce torque effort
Use same length bolts
Package components in order such that they are easily accessible as needed
during assembly.
Consider using pins thru interlocking members at section joint
connections.

*Suggested mods were made without knowing the launch/retrieve method.
```

4. Load Test Setup

4.a. Boundary Conditions

The bridge was supported along the underside of the end diaphragms with an 8” x 8” plastic reinforced composite beam. The pressure was applied to the deck thru ½ OSB wood sheet cut to 14” along the length of the bridge and 12” wide. All testing was conducted in load control and the cylinders were checked to be acting vertically prior to each load test.



4.b. Instrumentation

The bridge designer inspected the completed assembly and marked 65 strain gage locations on the bridge. The final gage locations are shown in Appendix A. The strain gage channels were sample checked with a calibrated strain gage indicator and found to be recording within 1 ue of the indicator. Similarly, the nominal resistances of the as-mounted gages were found to be well within allowable tolerance of the nominal resistance of their gage specification when queried by the DAQ control system. A network of three thermocouples was mounted near the gages for temperature recording and compensation.

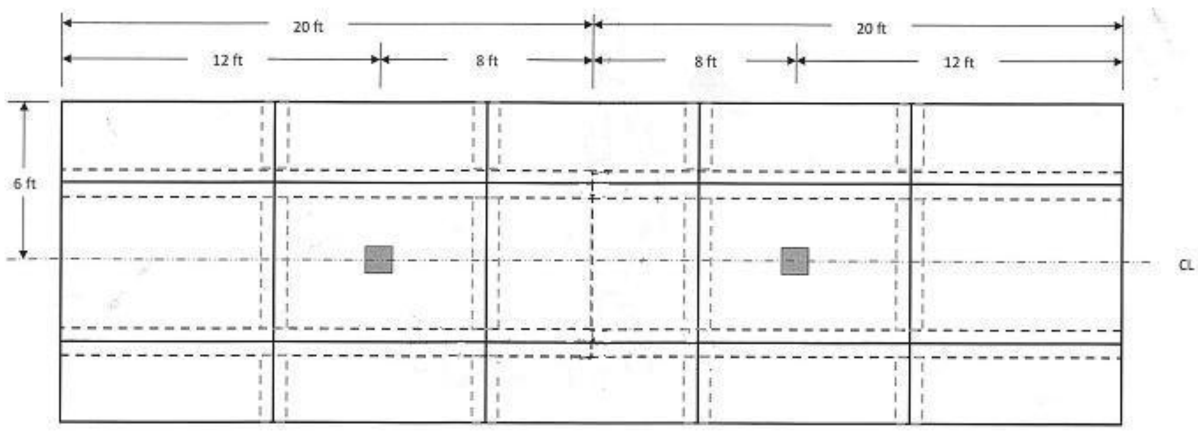
Ten LVDTs were mounted on the bridge to determine the deflection throughout the loading. The locations are shown in Appendix A. The accuracy of each LVDT was checked with machinery shims after they were mounted on the bridge and found accurate within 1/100”. One LVDT was mounted at each end of the bridge to account for compression of the bridge supports during loading.

The bridge loading was controlled via load cell feedback. Each load cell display used in testing was calibrated to a NIST-traceable load display system prior to the first test and found to be accurate within 100lbs.

4.c. Loading

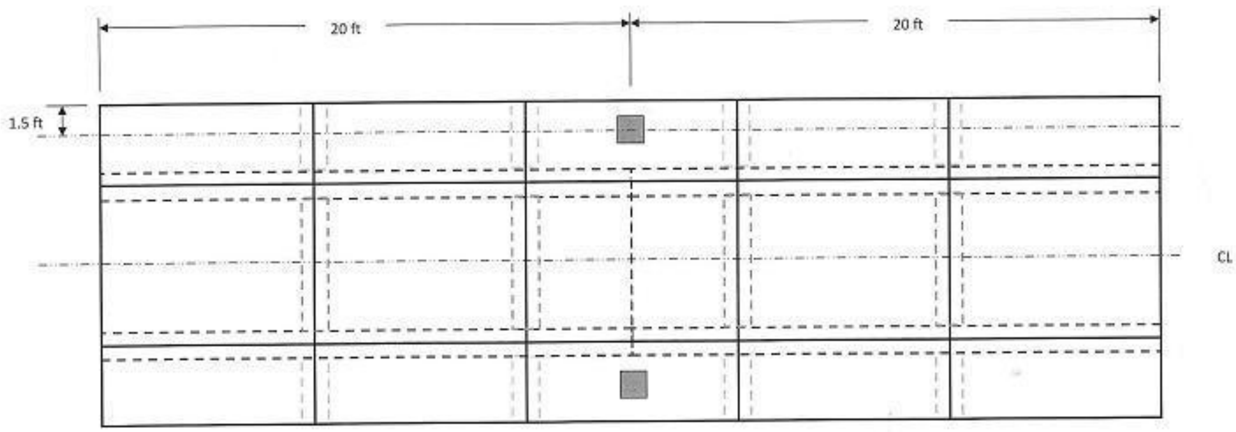
Four load configurations were tested. Each was applied in increments and decrements of 5% of the peak load except as indicated.

The first load configuration was loading on the centerline of the bridge width and 8 feet from the mid-span. Test #1 applied 20,000 lbs. at each pad location to check the bridge, load system and data acquisition system. Test #2 applied 90,000 lbs. at each pad in 5,000 lbs increment and decrements.



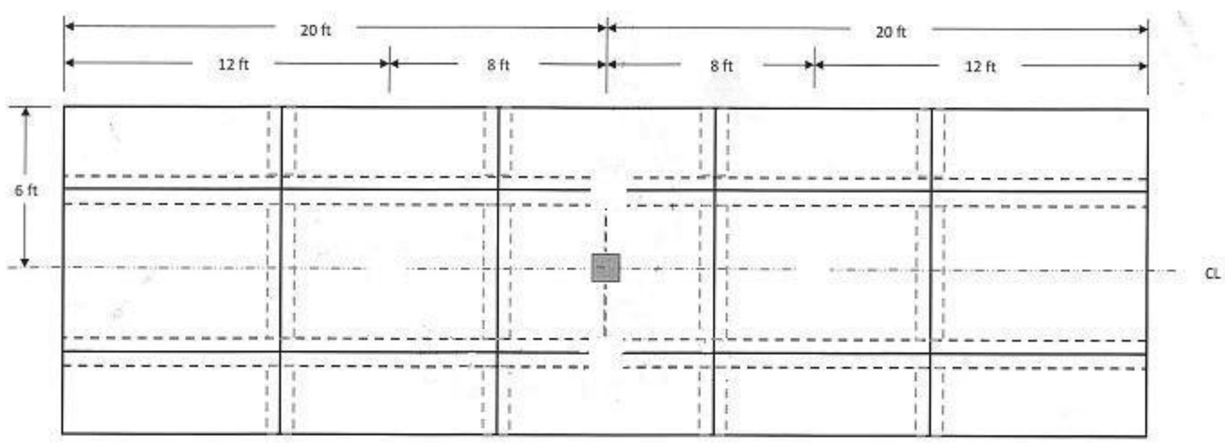
First Load Configuration Pad locations used in Test #1 & #2.

The second load configuration was loading at the mid-span and 1.5 feet from each edge of the bridge. Test #3 applied 85,000 lbs at each pad in 5,000 lbs increment and decrements, test #4 applied 100,000 lbs at each pad in increments, but did not offload in decrements, and test #5 applied 100,000 lbs at each pad in increments and decrements.



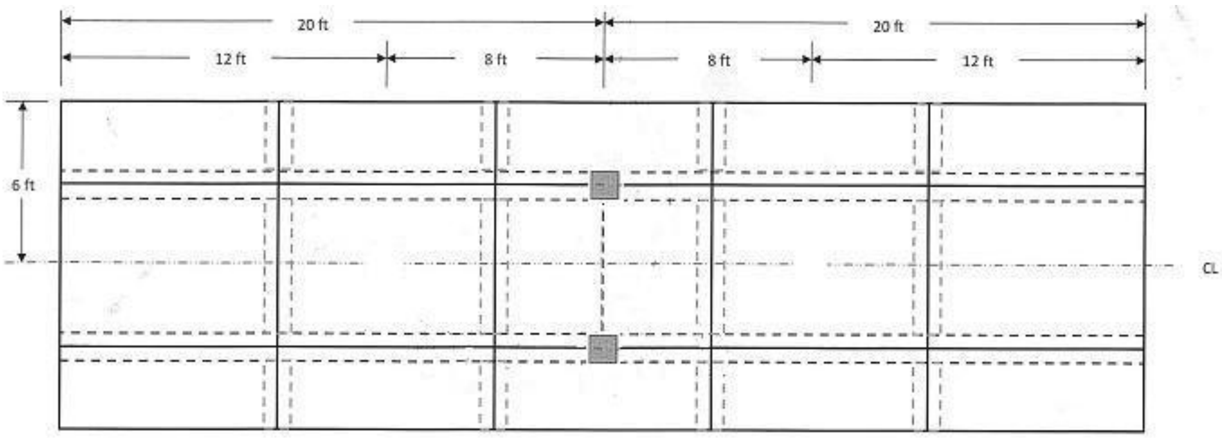
Second Load Configuration Pad locations used in Test #3, #4, & #5.

The third load configuration was loading a single pad in the center of the bridge deck at mid-span. Test #6 applied 100,000 lbs in increments and offloaded in decrements.



Third Load Configuration Pad location used in Test #6.

The fourth configuration was loading at the mid span and directly over the tub girder webs. Test #7 applied 100,000 lbs at each pad in increments and decrements.



Fourth Load Configuration Pad locations used in Test #7.

4.d. Data Collection Procedure

For each test, data recording began prior to resting the load actuators on the bridge. Three camcorders were set to record HD video of the bridge from the right and left banks, and center span. Then the DAQ system was checked and the strain gages and LVDTs were zeroed. Actuators were then lowered onto the bridge and the cylinders aligned vertically over the center of the pads. The bridge loads were then stepped to the appropriate command load using quarter sine wave transitions. Each transition occurred over approximately 1 minute. Once the step was held and stable readings recorded, the next step was commanded. This continued until the loads were completely removed. Data collection continued for minutes afterward to observe any delayed effects before recording was stopped.

5. Findings

5.a. Data Processing

Raw data was exported to a computer for processing and the time at which stable readings for each load step was recorded was found. Readings at this time were extracted to establish Load vs. Strain, and Load vs. Deflection curves.

The deflection measurement data was processed to determine the deflection in the bridge due to loading and to ignore the deflection due to the banks settling. Deflections were corrected for the effects of bank support settling by subtracting the geometric effect of the bank deflection from each respective bridge deflection measurement. Similarly, since deflection of the center span side deck panel in Test 3, 4, and 5 were visible, an effort to determine the deflection within the plate alone was attempted.

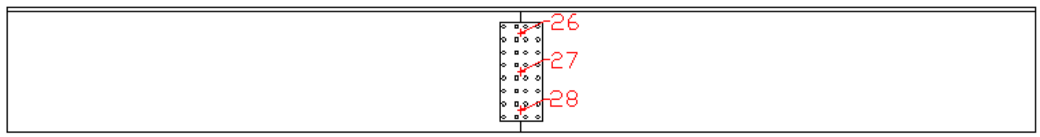
5.b. Peak Readings

The peak strain and strain gage location are shown below along with the peak deflection for each test.

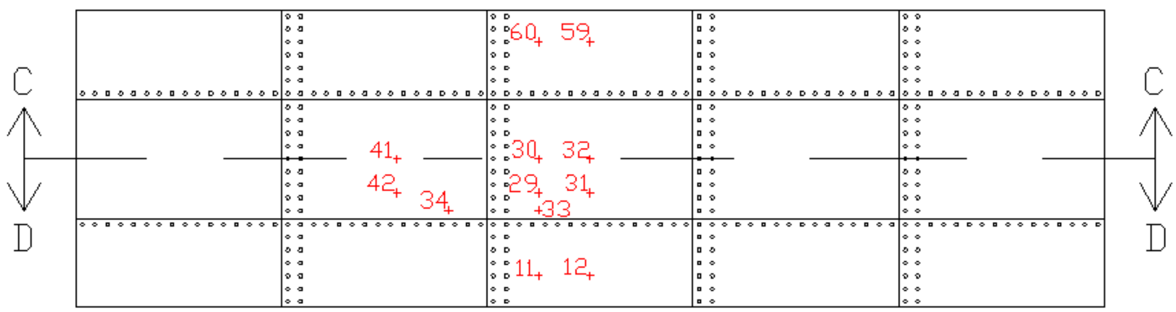
Test #1	218ue	@ Gage #41	-0.0225”	@ LVDT #4
Test #2	963ue	@ Gage #41	-0.145”	@ LVDT #4
Test #3	971ue	@ Gage #59	-0.159”	@ LVDT #4
Test #4	982ue	@ Gage #59	-0.1955”	@ LVDT #4
Test #5	1046ue	@ Gage #59	-0.1975”	@ LVDT #4
Test #6	840ue	@ Gage #32	-0.0965”	@ LVDT #4
Test #7	207ue	@ Gage #15	-0.193”	@ LVDT #4

APPENDIX A

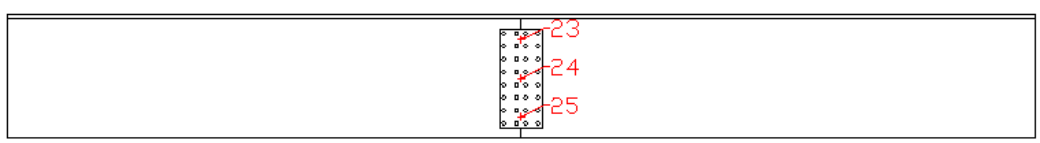
STRAIN GAGE LOCATIONS



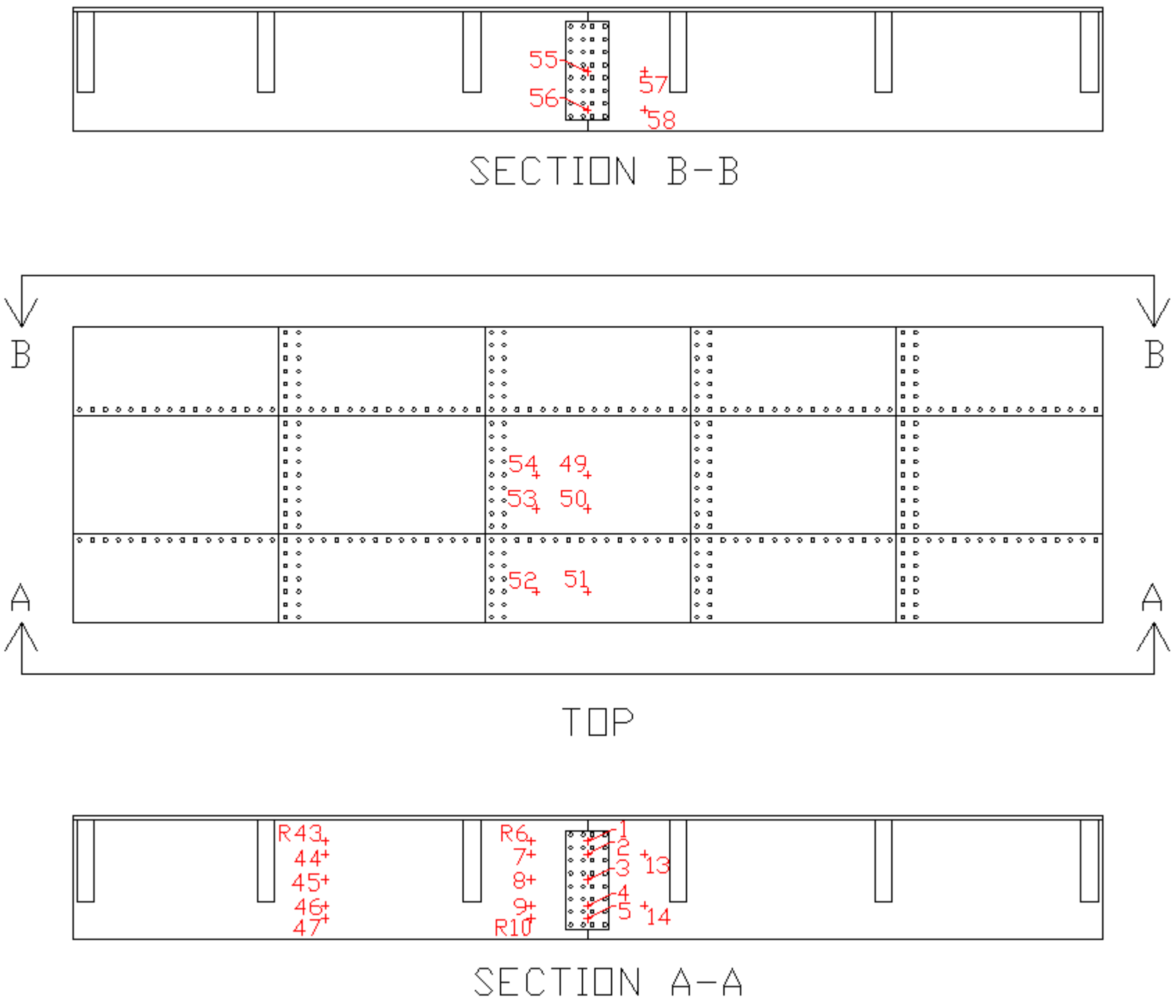
SECTION C-C



TOP OF INSIDE



SECTION D-D


55
56
57
58
SECTION B-B
B
B
54
49
53
50
52
51
A
A
TOP
R43
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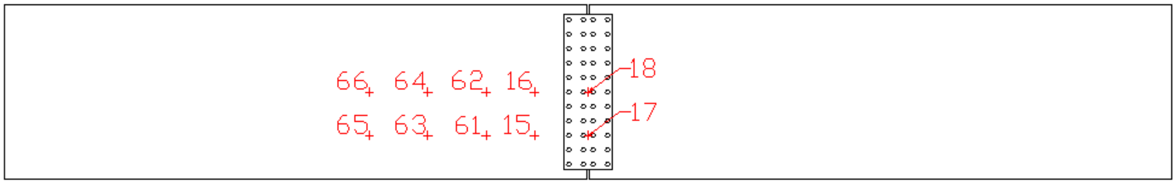
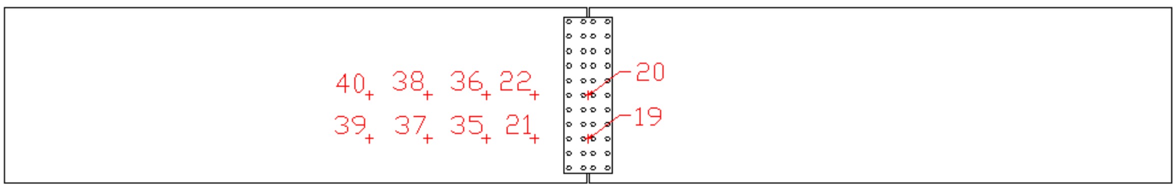
5
13
14
SECTION A-A

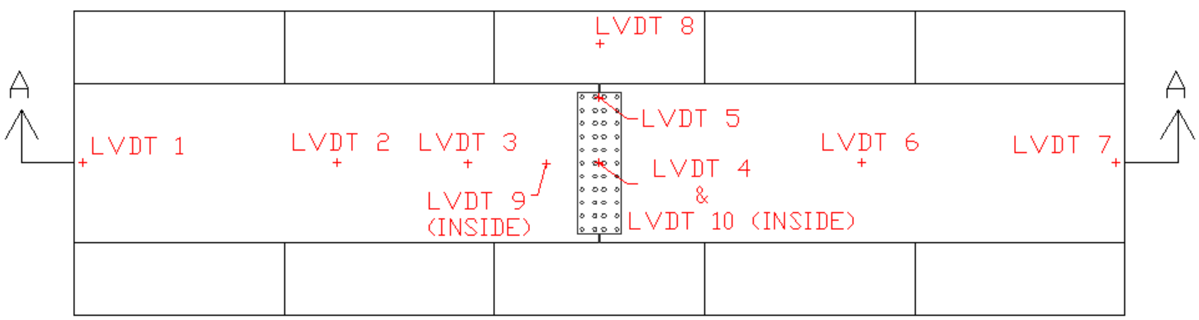


BOTTOM

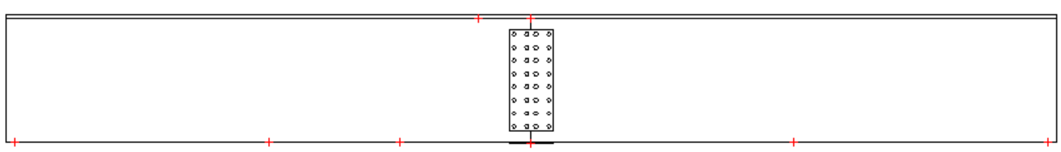


INSIDE FLOOR

LVDT LOCATIONS



TOP



SECTION A-A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2
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4
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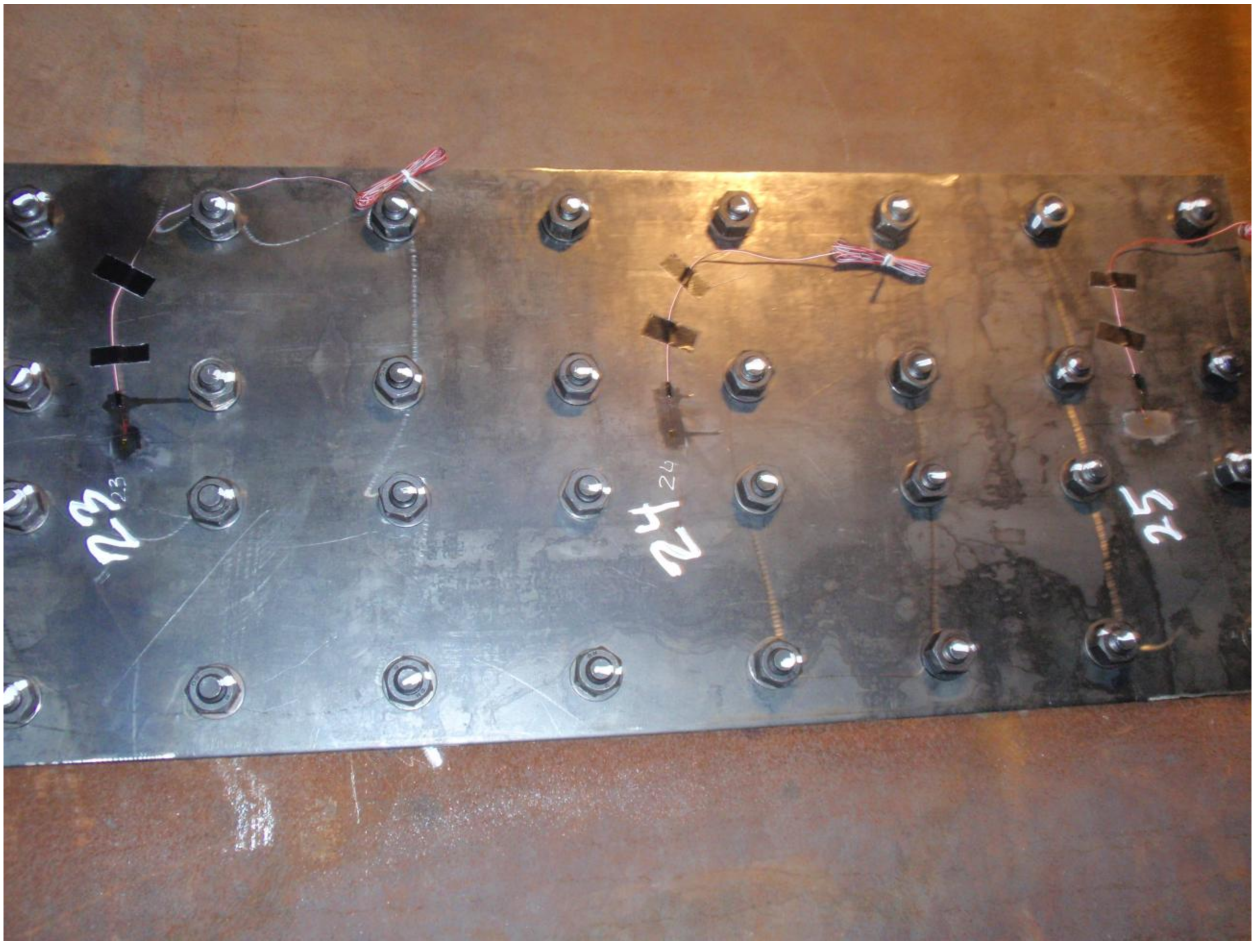
13
14


19
20


21
22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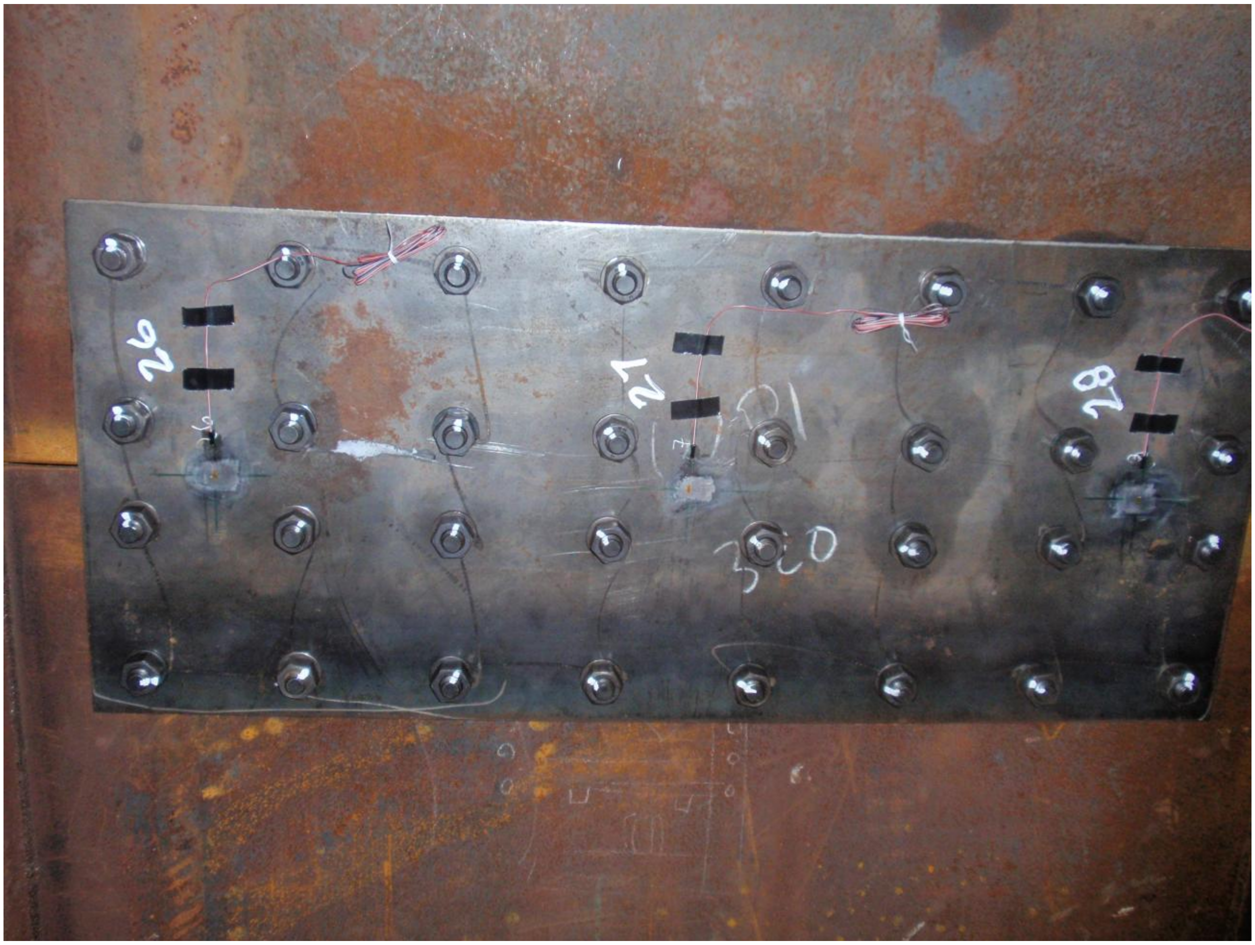
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52
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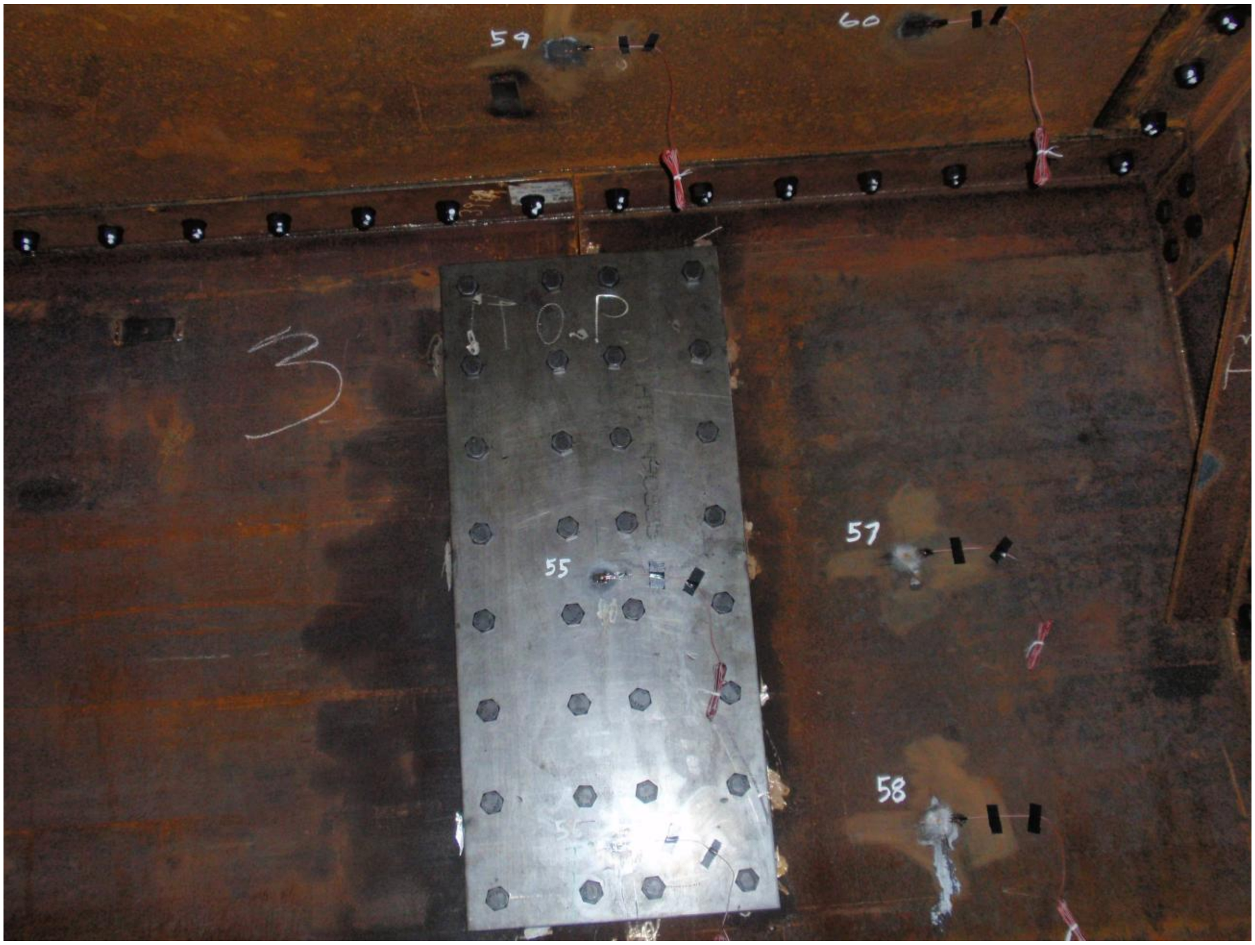
59
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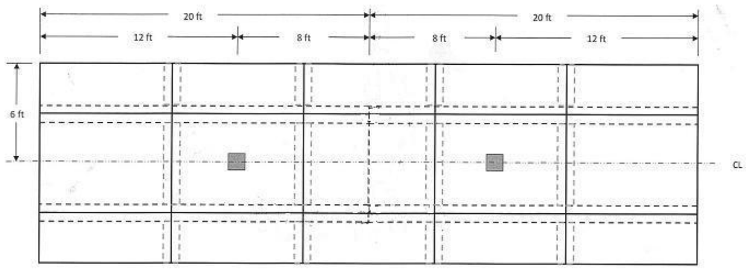
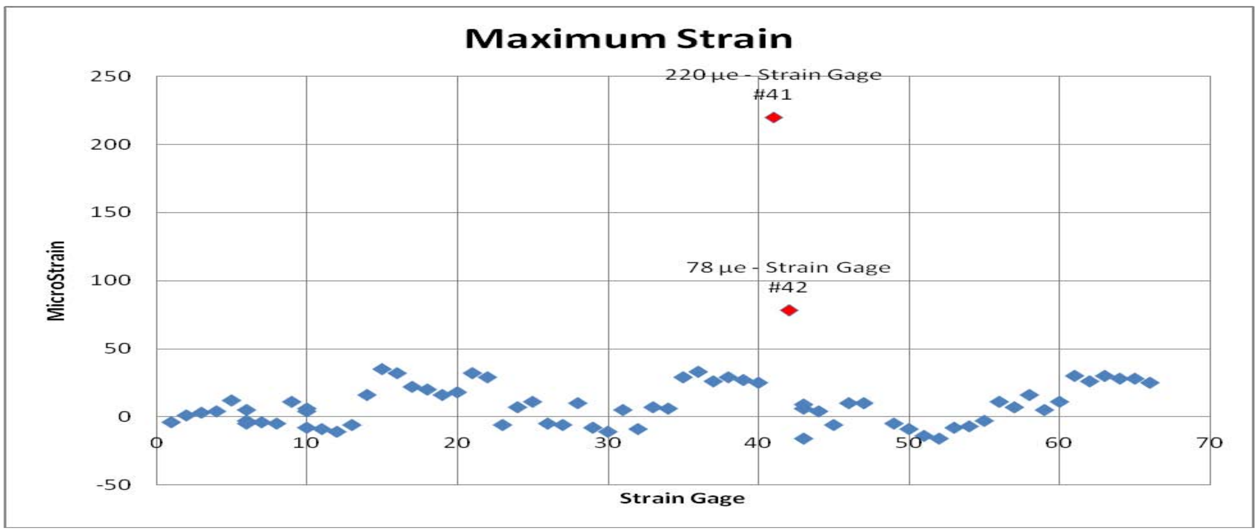
TOP
3
55
57
58

APPENDIX B

TEST #1



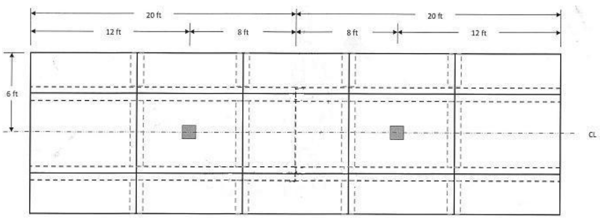
LOAD POSITIONS - 20,000 lbs./pad



Down	Negative										
Up	Positive										
									TOP VIEW		

								-0.002	Relative to the Bridge					
							x	-0.0835	Relative to the Ground					
							x	-0.0815						
x			x		x		x	-0.0805			x			x
			-0.08175		-0.08463						-0.07925			

DEFLECTION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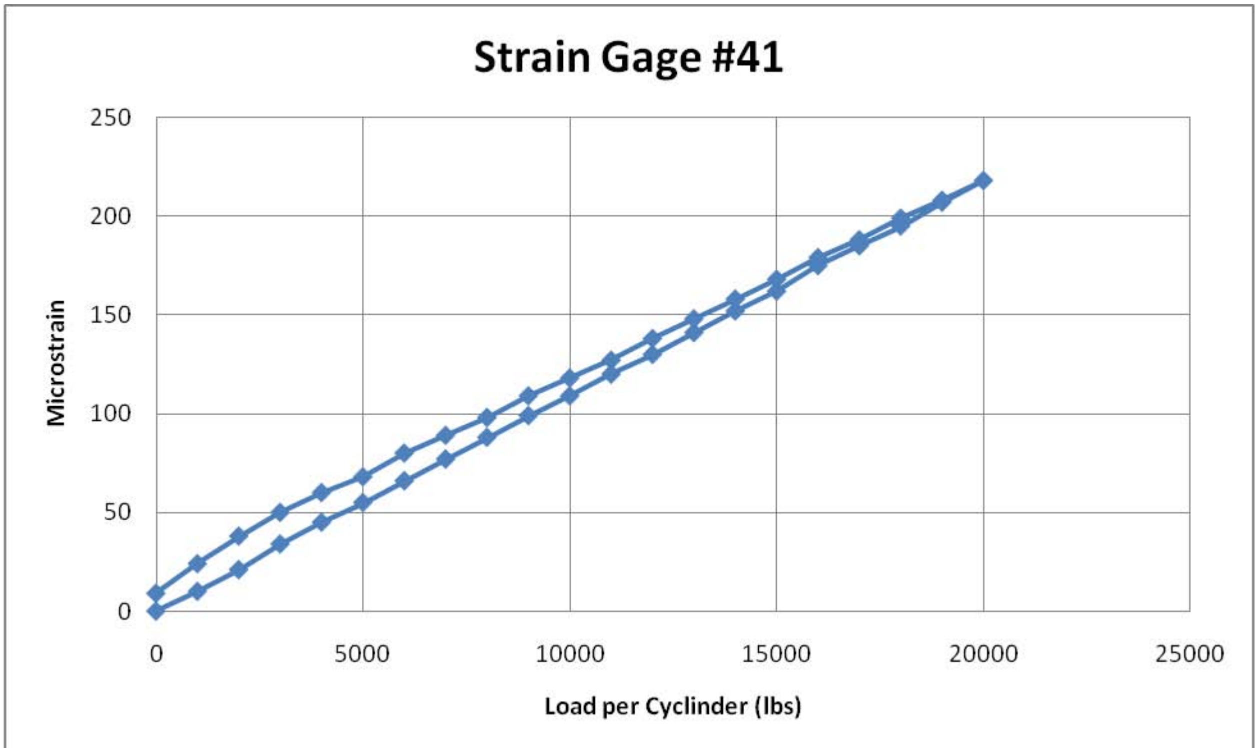
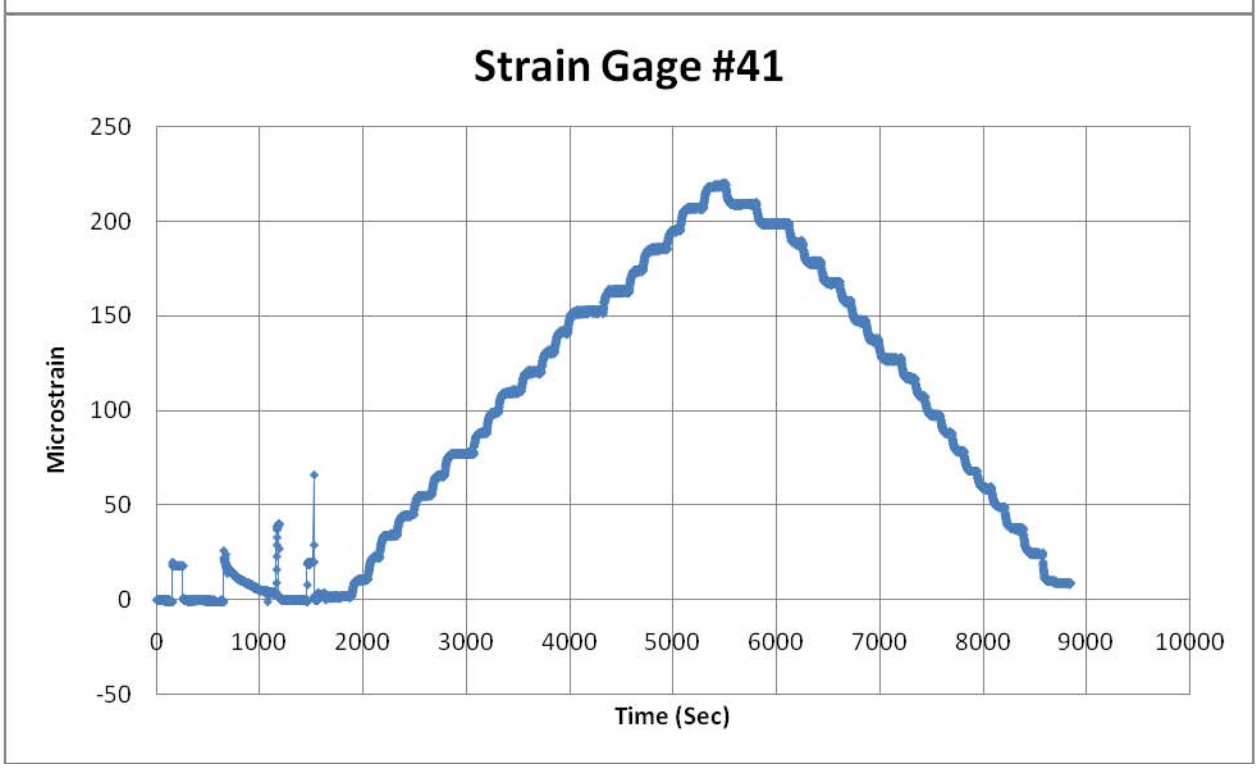
12 ft
8 ft
8 ft
12 ft
6 ft
CL


Strain Gage #41
Microstrain
Load per Cyclinder (lbs)
250
200
150
100
50
0
0
5000
10000
15000
20000
25000


Strain Gage #41
Microstrain
Time (Sec)
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50
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-50
0
1000
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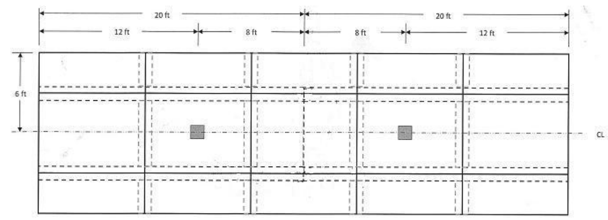
3000
4000
5000
6000
7000
8000
9000
10000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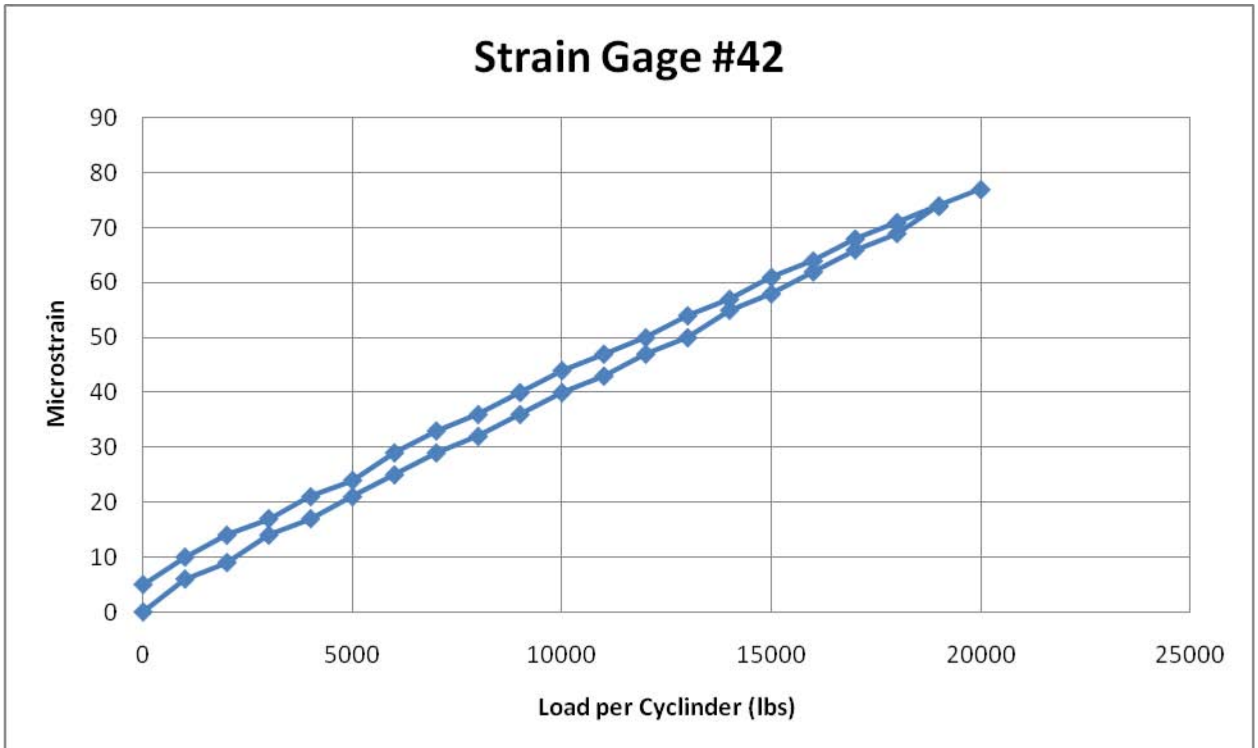
Strain Gage #42
Microstrain
Load per Cyclinder (lbs)
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40
50
60
70
80
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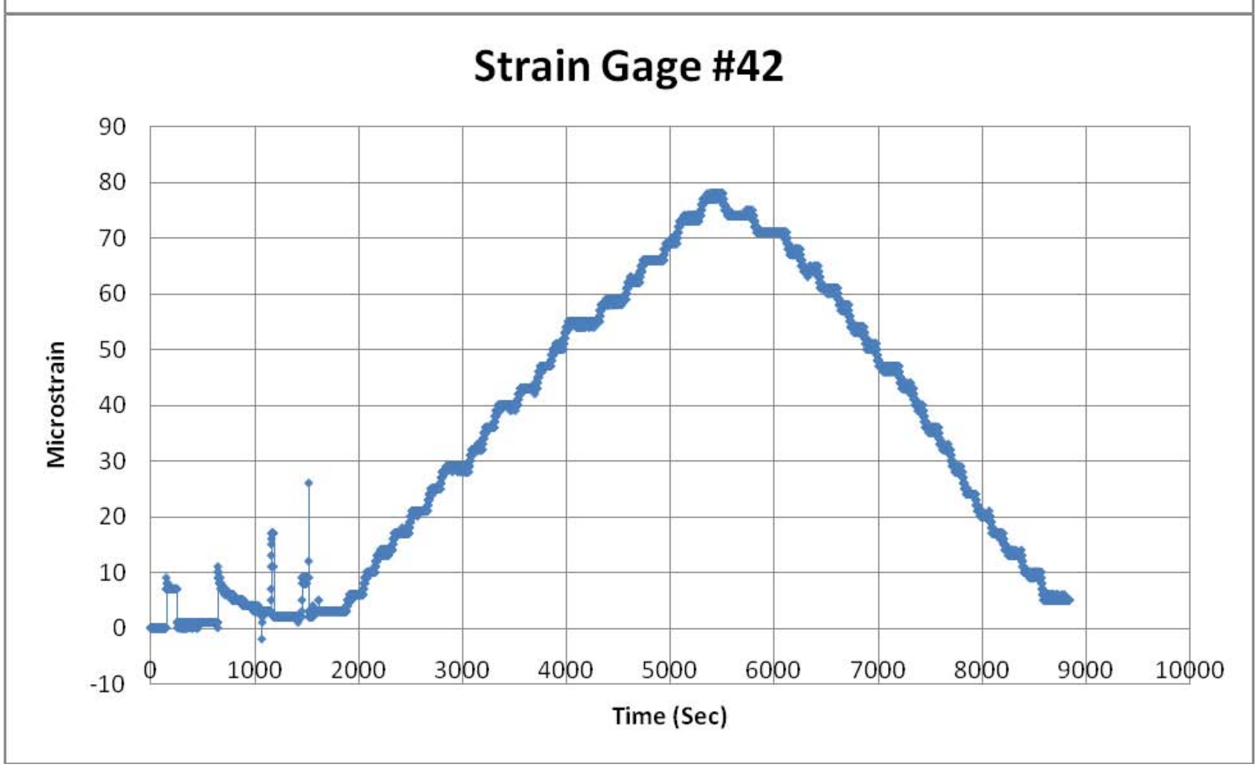
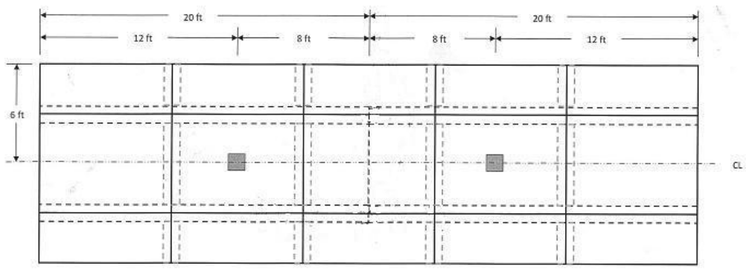
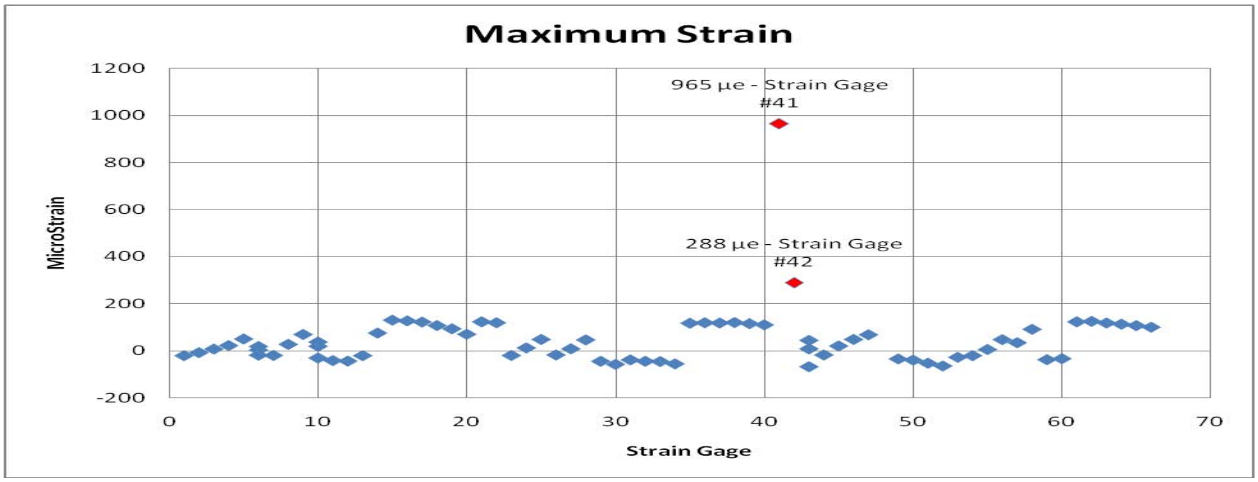
0
5000
10000
15000
20000
25000


Strain Gage #42
Microstrain
Time (Sec)
-10
0
10
20
30
40
50
60
70
80
90
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

TEST #2



LOAD POSITIONS - 90,000 lbs./pad



			Down	Negative										
			Up	Positive										
									TOP VIEW					
								0.002	Relative to the Bridge					
							x	-0.1395	Relative to the Ground					
							x	-0.1415						
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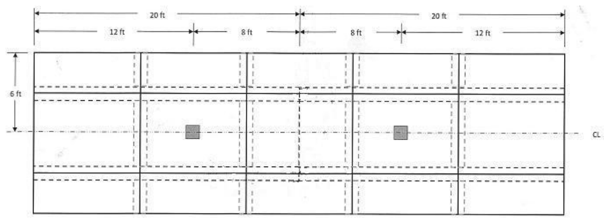
			-0.13225		-0.14388						-0.10075			

DEFLECTION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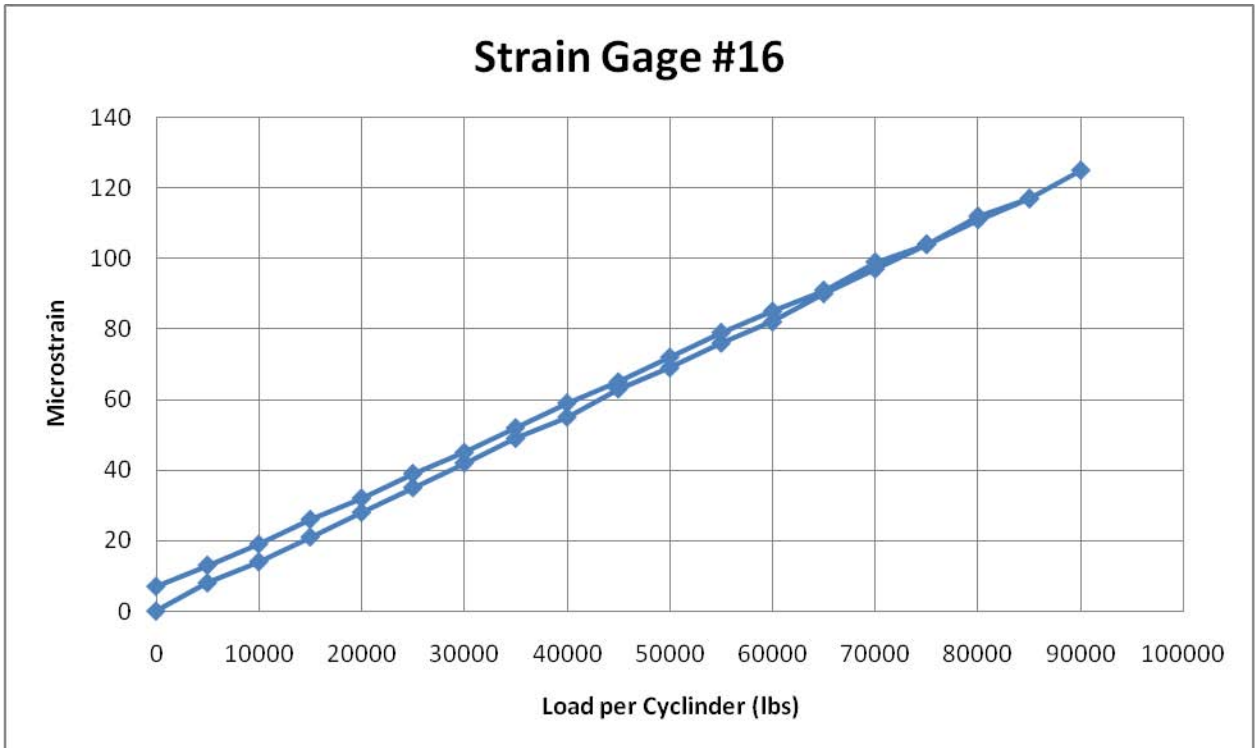
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Microstrain
Load per Cyclinder (lbs)
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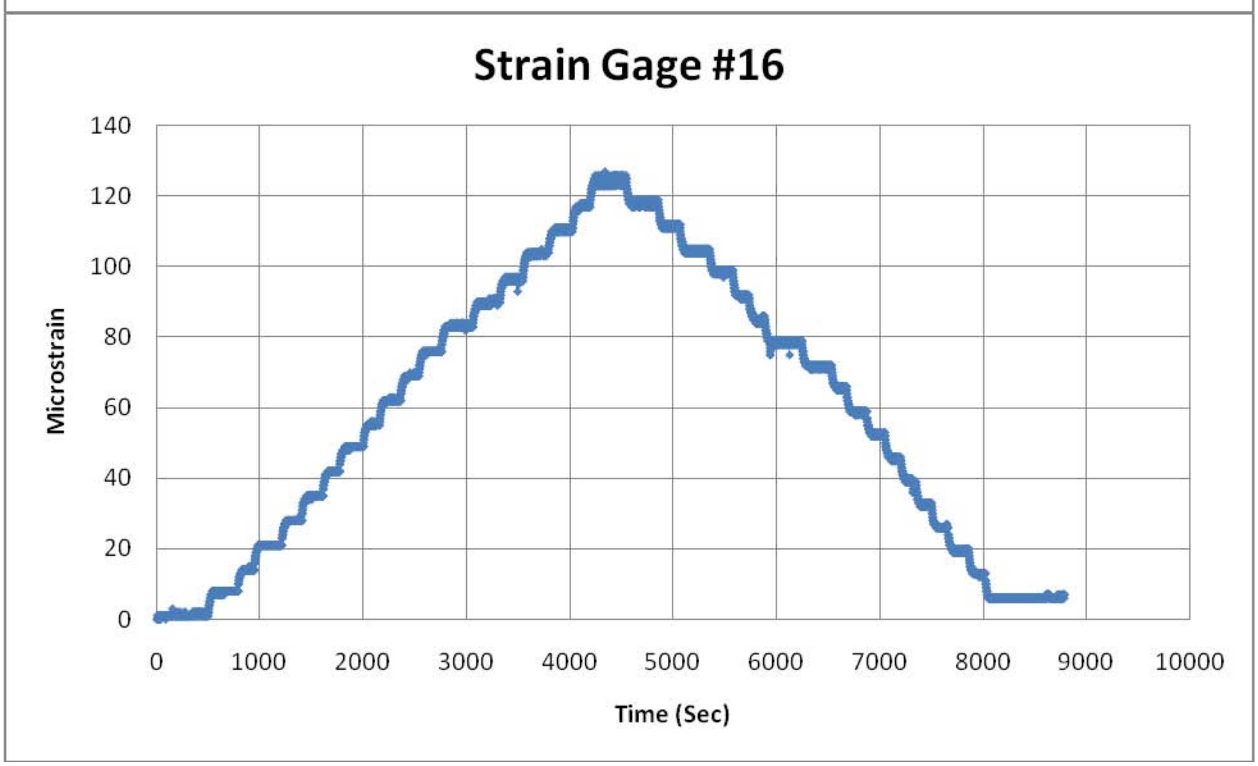
70000
80000
90000
100000


Strain Gage #16
Microstrain
Time (Sec)
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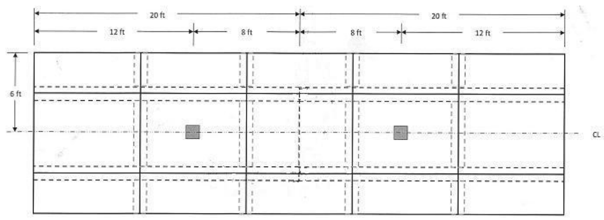
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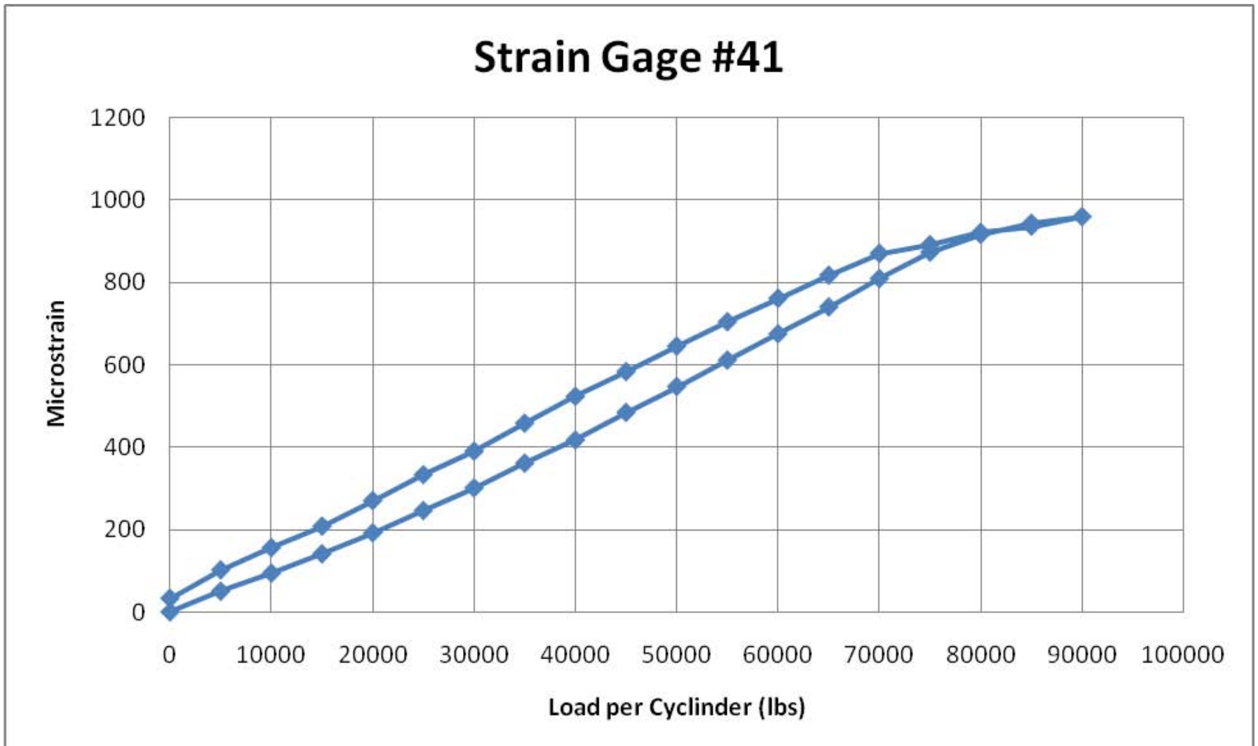
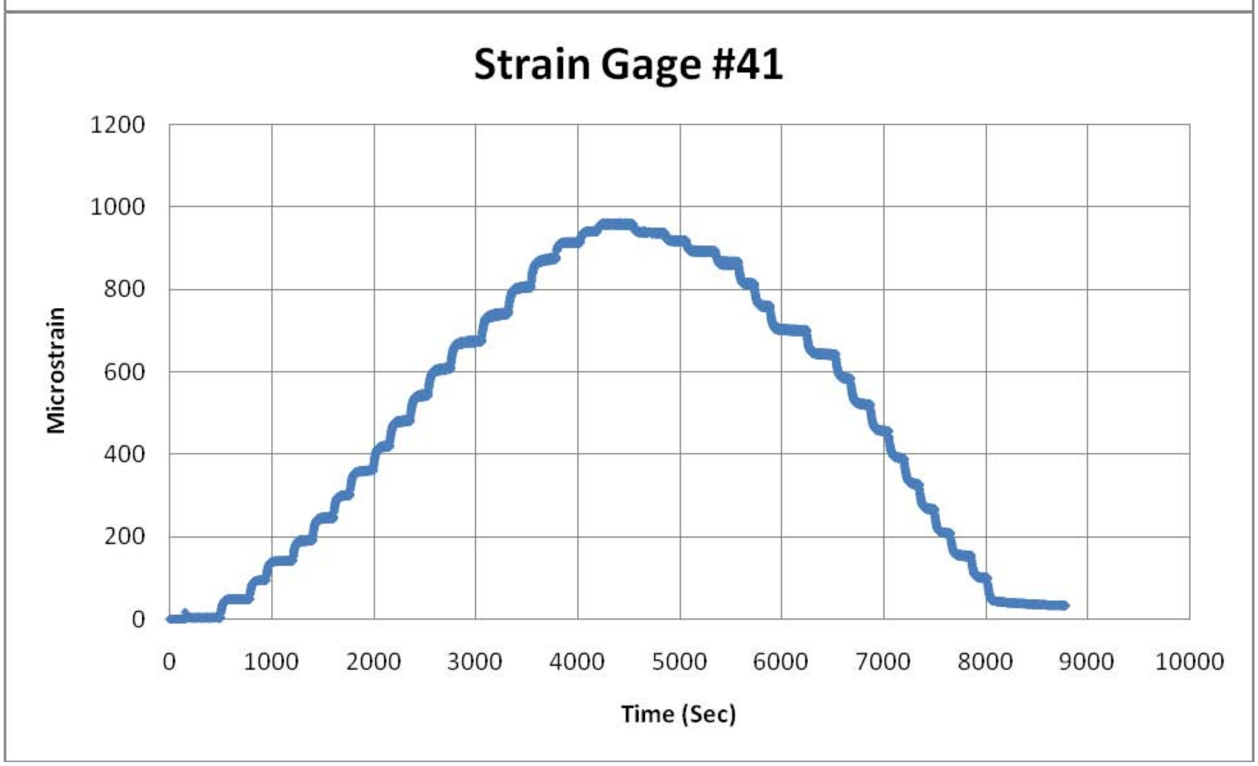
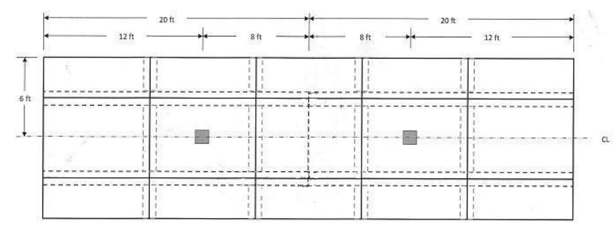
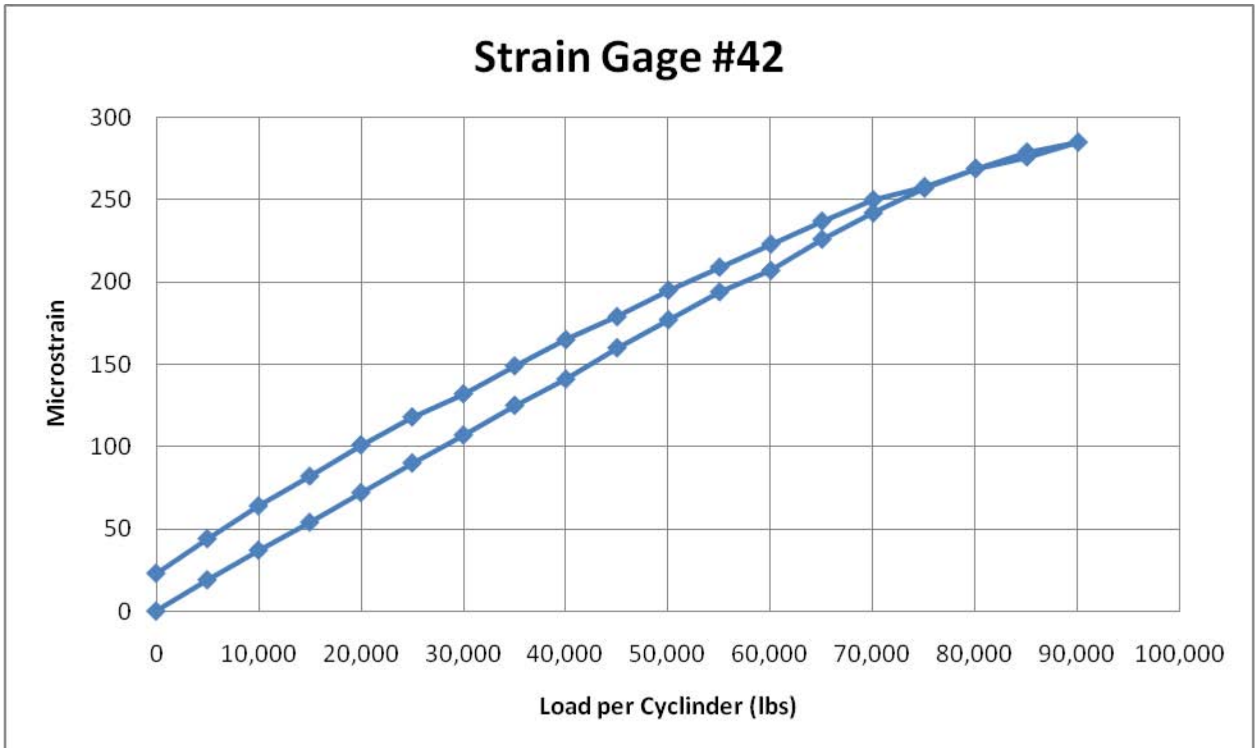
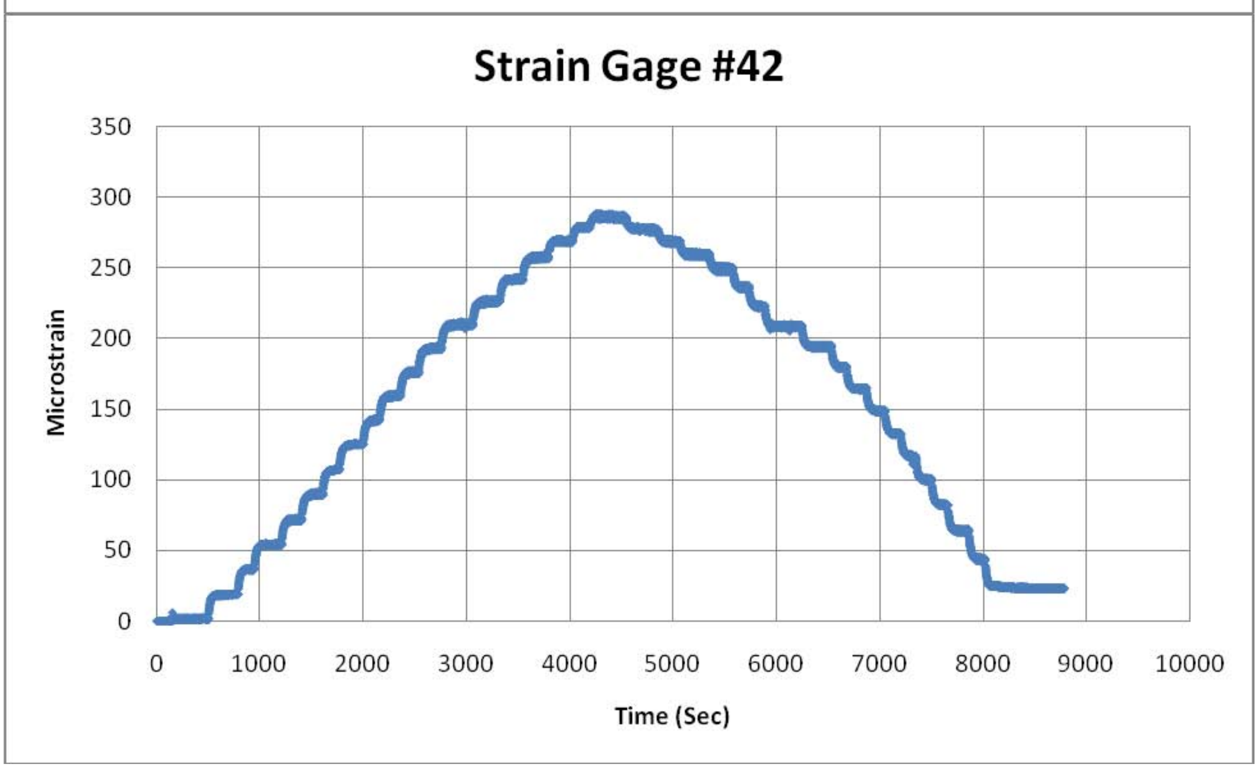

Strain Gage #41
Microstrain
Load per Cyclinder (lbs)
0
200
400
600
800
1000
1200
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000

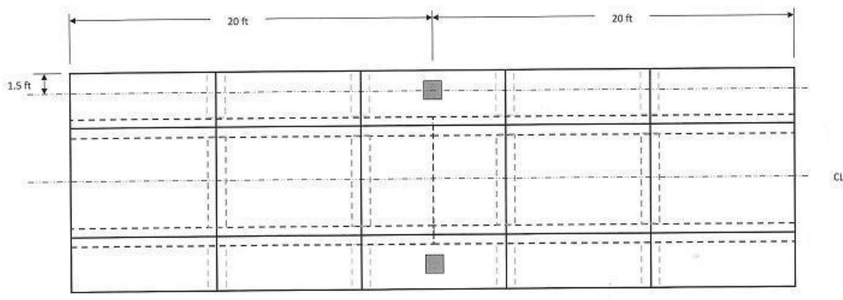

Strain Gage #41
Microstrain
Time (Sec)
0
200
400
600
800
1000
1200
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000


20 ft
20 ft
12 ft
8 ft
8 ft
12 ft
6 ft
CL

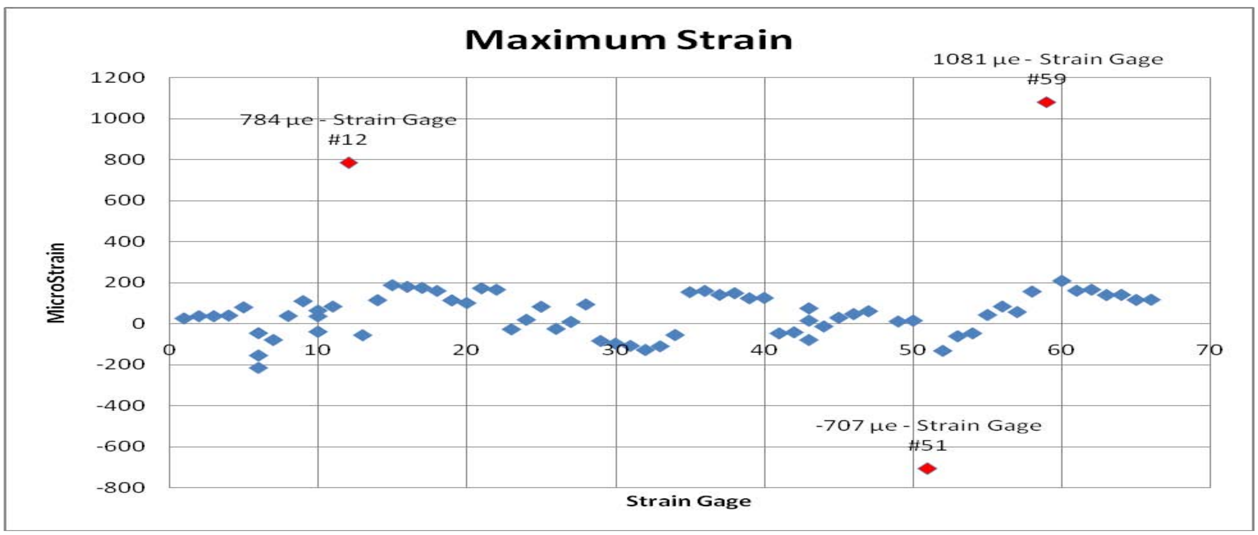

Strain Gage #42
Microstrain
300
250
200
150
100
50
0
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
Load per Cyclinder (lbs)


Strain Gage #42
Microstrain
350
300
250
200
150
100
50
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Time (Sec)

TEST #3



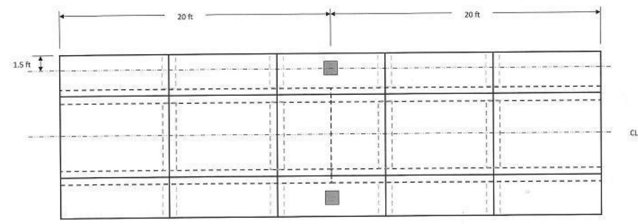
LOAD POSITIONS - 85,000 lbs./pad

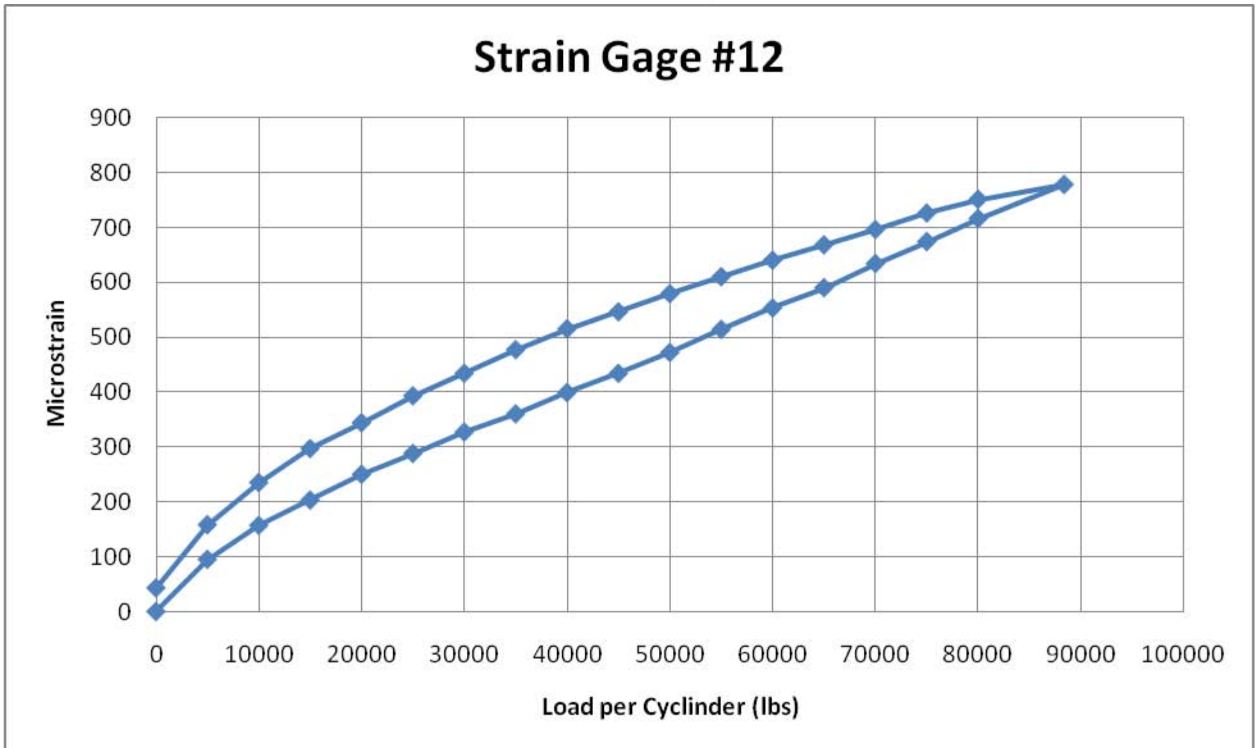


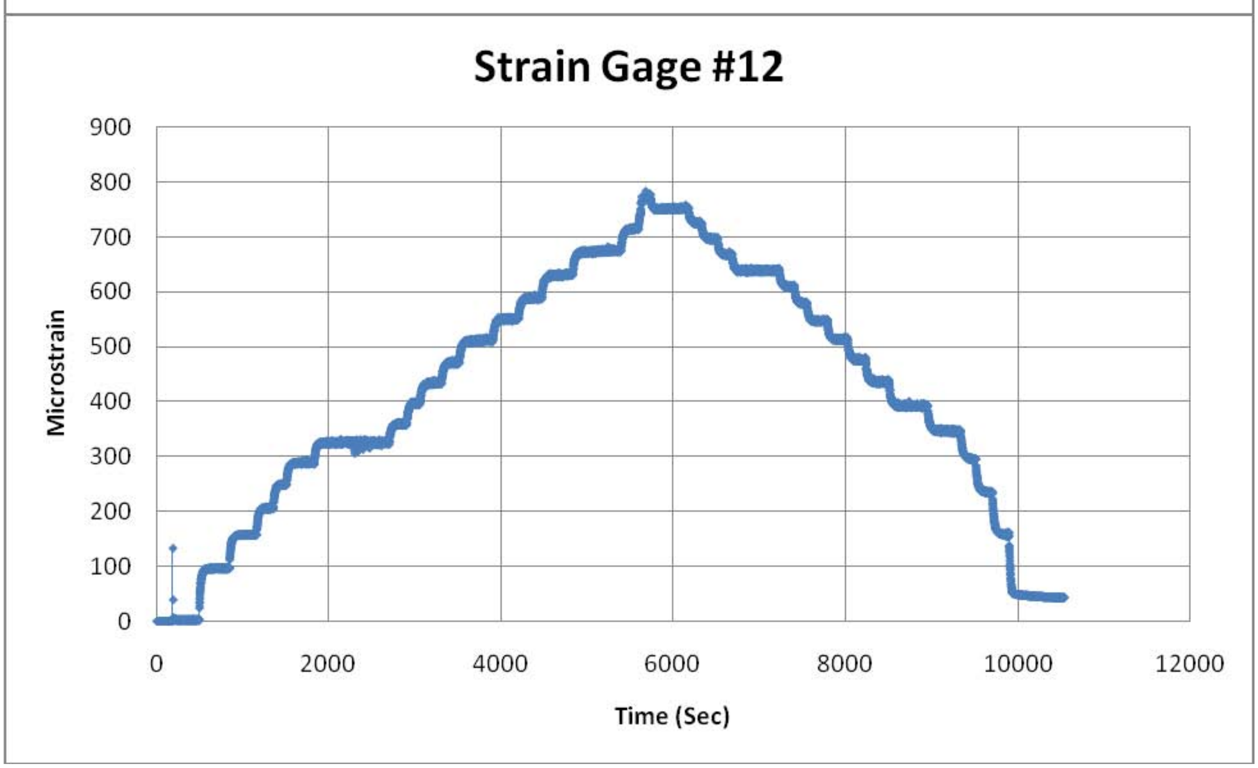
Down	Negative									
Up	Positive									
									TOP VIEW	

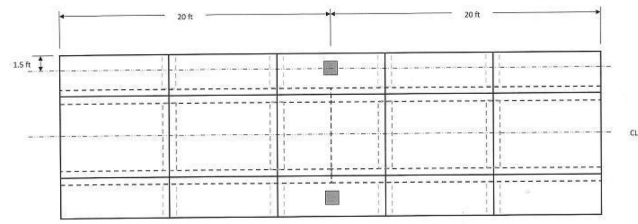
							Corrected							
								-0.626	Relative to the Bridge					
							x	-0.827	Relative to the Ground					
							x	-0.201						
x			x		x		x	-0.185			x			x
			-0.142		-0.1685						-0.118			

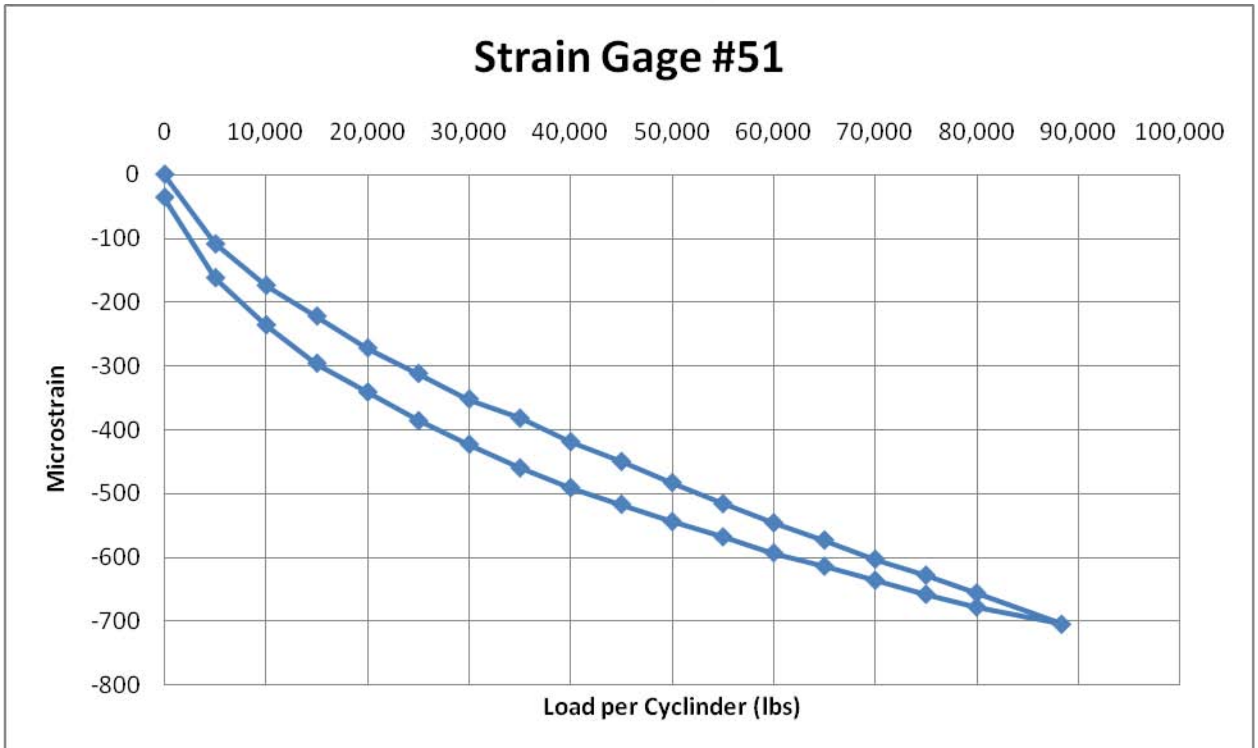
DEFLECTION

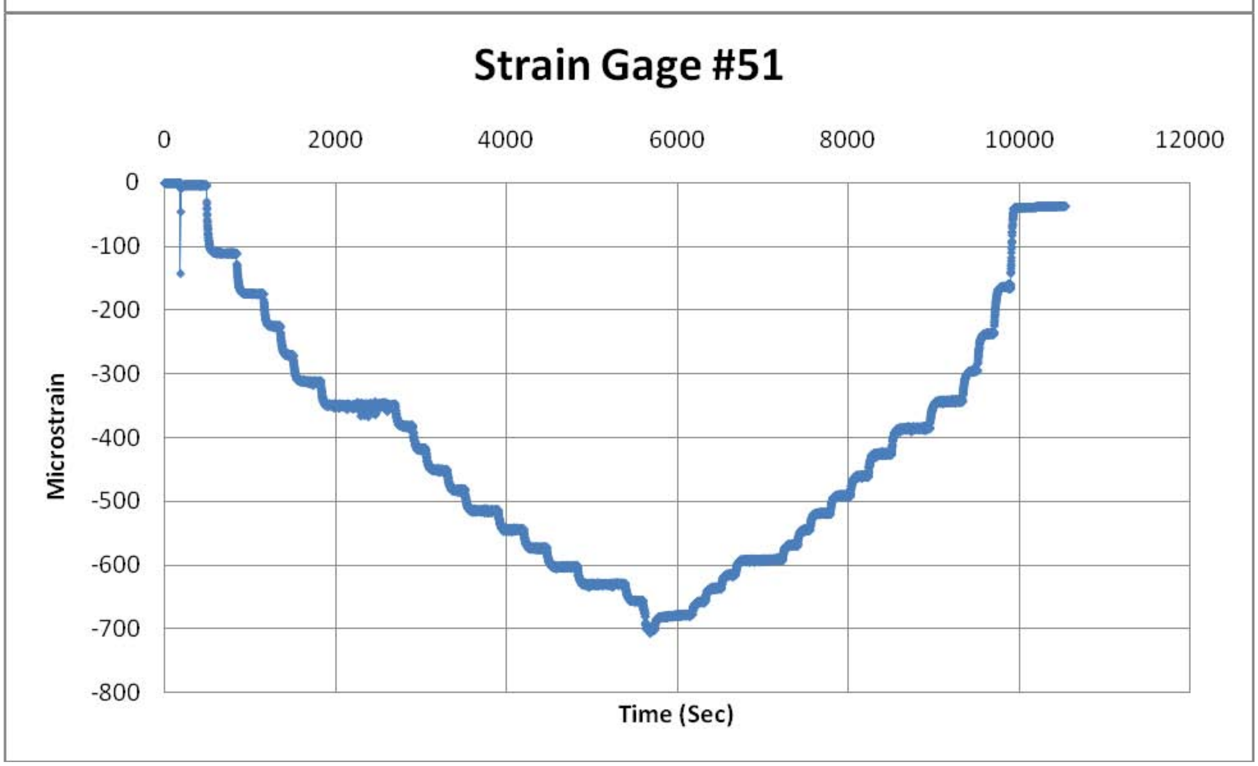


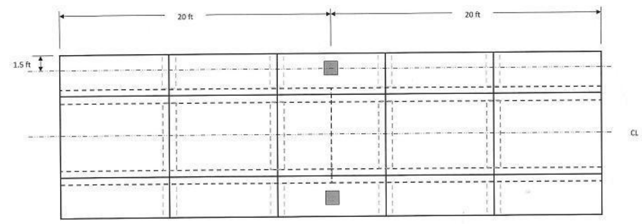

Strain Gage #12
Microstrain
Load per Cyclinder (lbs)
0
100
200
300
400
500
600
700
800
900
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000

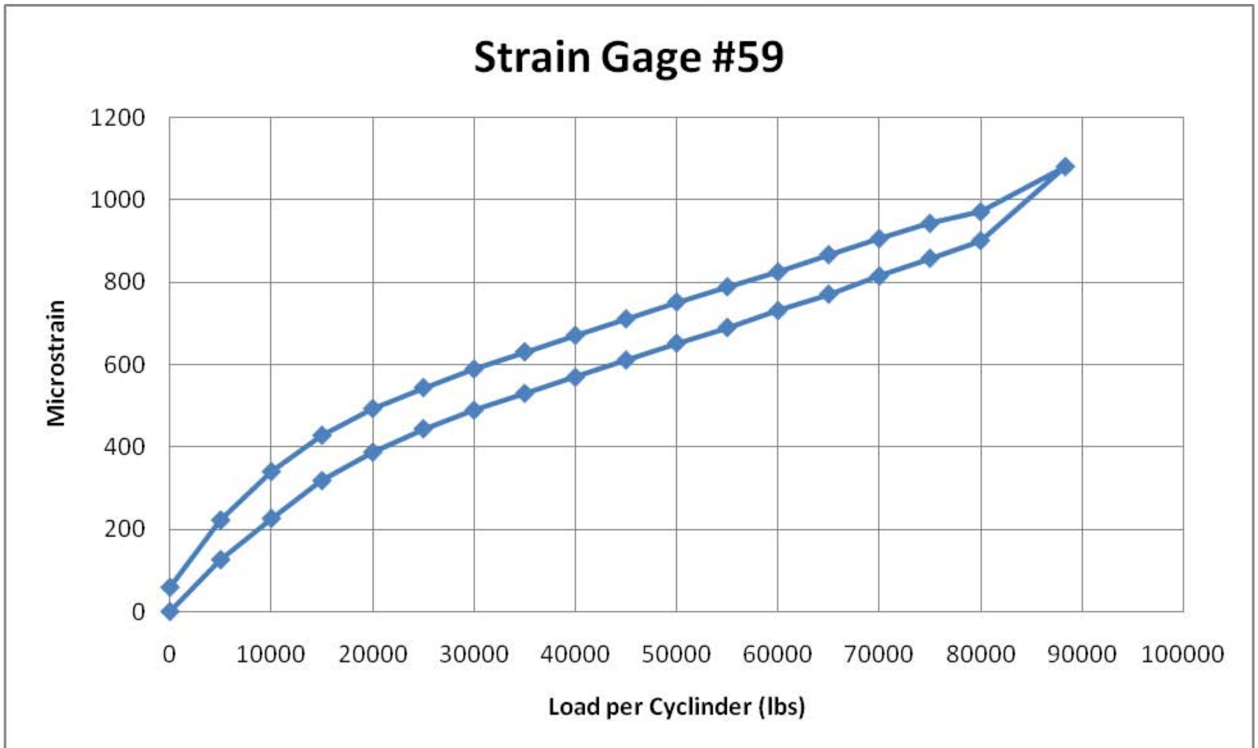

Strain Gage #12
Microstrain
Time (Sec)
0
100
200
300
400
500
600
700
800
900
0
2000
4000
6000
8000
10000
12000

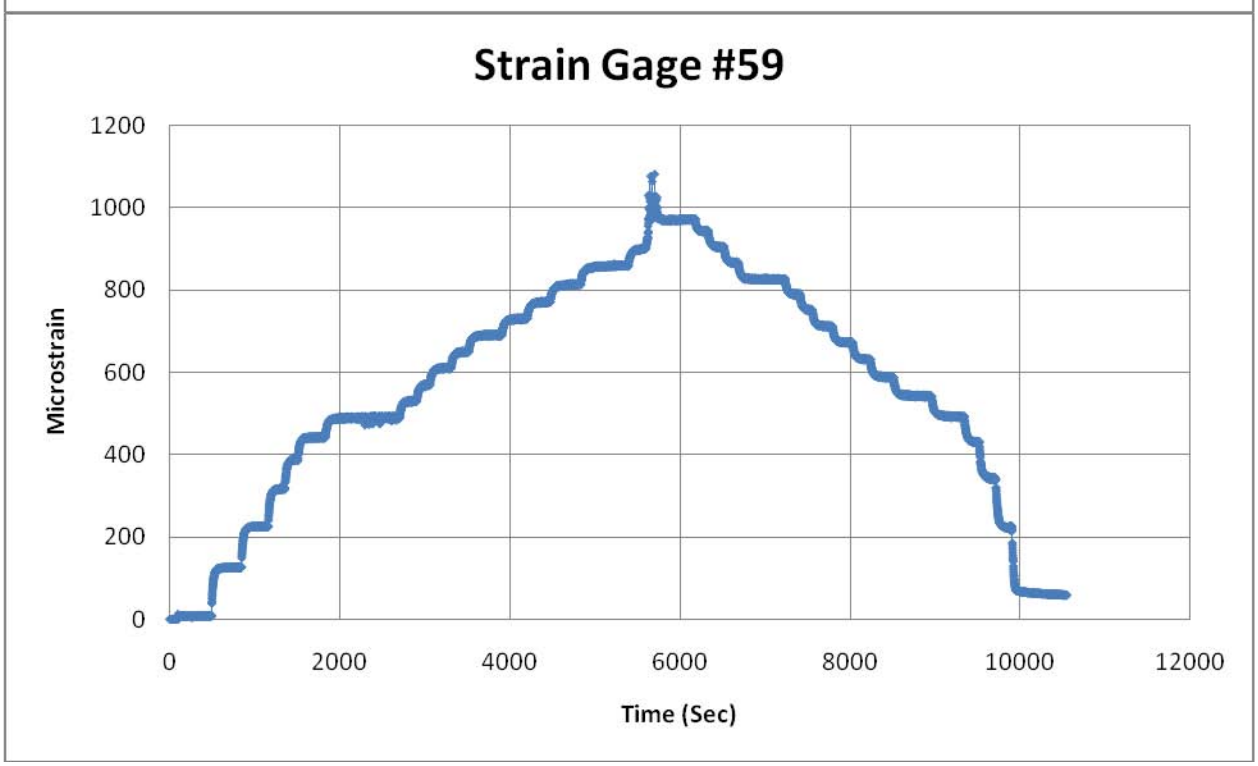

20 ft
20 ft
1.5 ft
CL


Strain Gage #51
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
0
-100
-200
-300
-400
-500
-600
-700
-800
Microstrain
Load per Cyclinder (lbs)

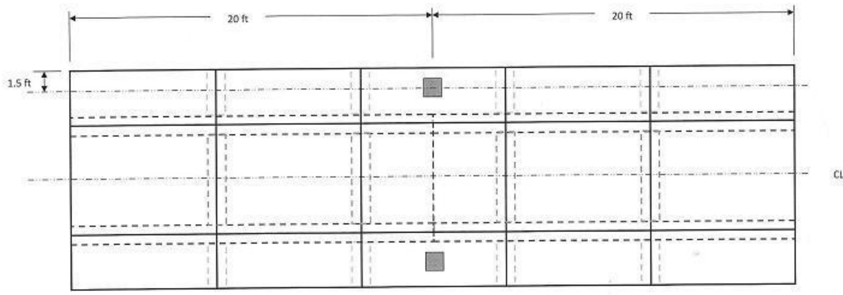

Strain Gage #51
0
2000
4000
6000
8000
10000
12000
0
-100
-200
-300
-400
-500
-600
-700
-800
Microstrain
Time (Sec)


20 ft
20 ft
1.5 ft
CL

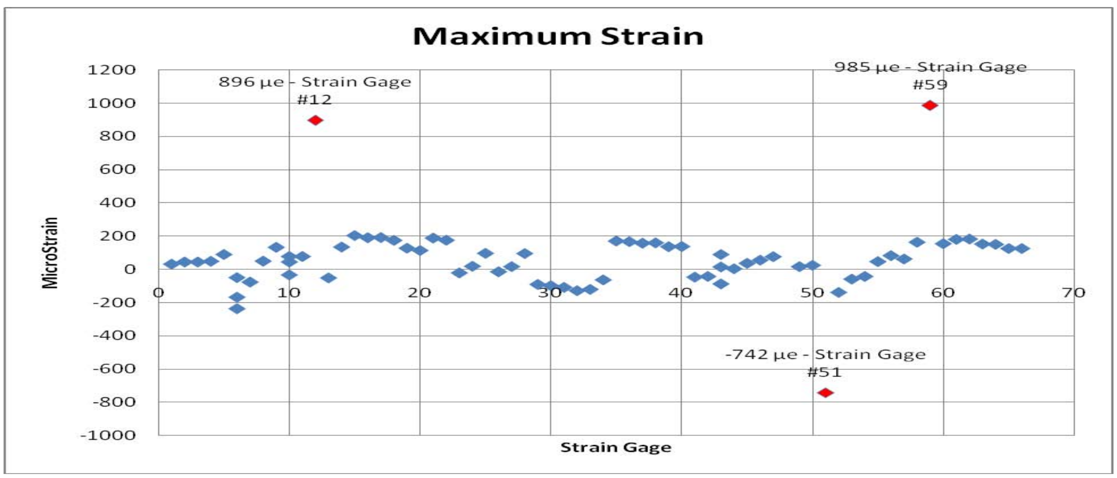

Strain Gage #59
Microstrain
Load per Cyclinder (lbs)


Strain Gage #59
Microstrain
Time (Sec)

TEST#4



LOAD POSITIONS - 100,000 lbs./pad

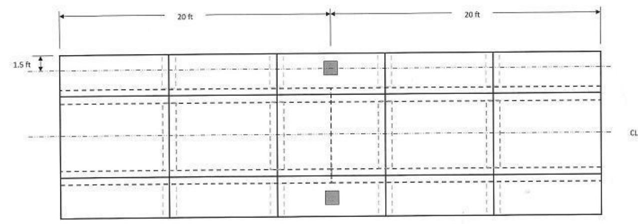


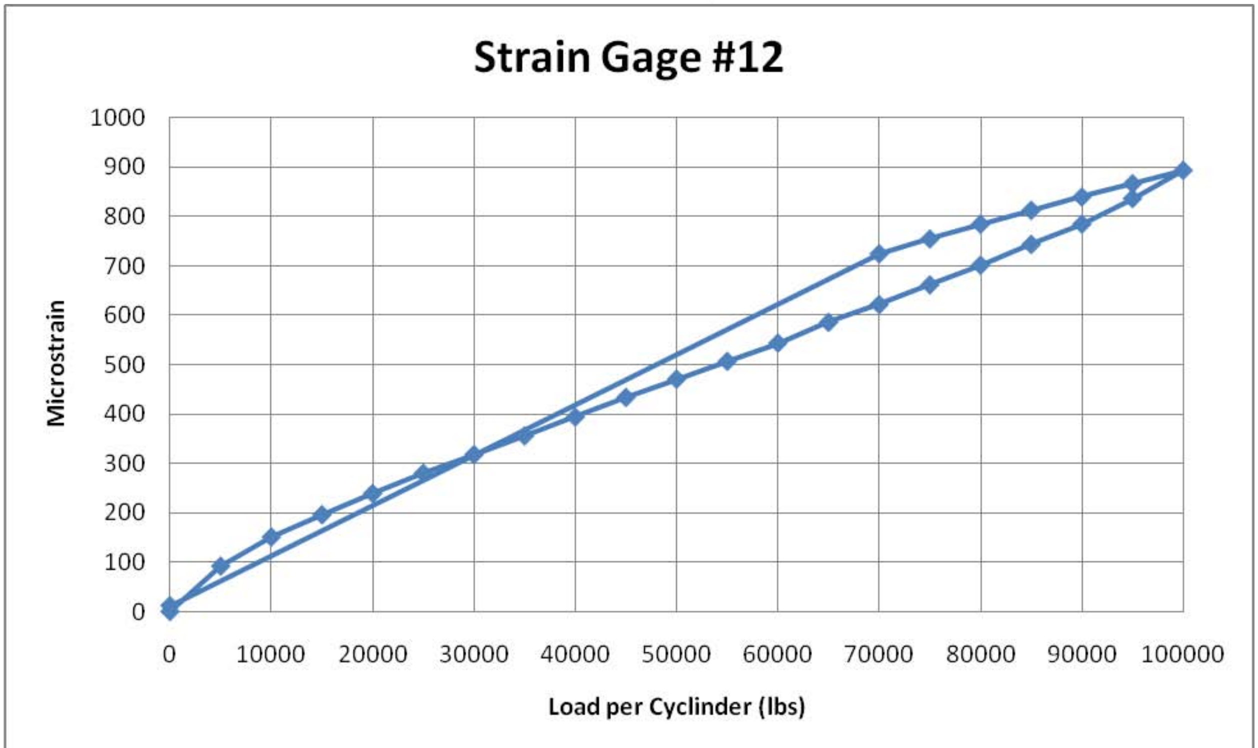
Down	Negative
Up	Positive

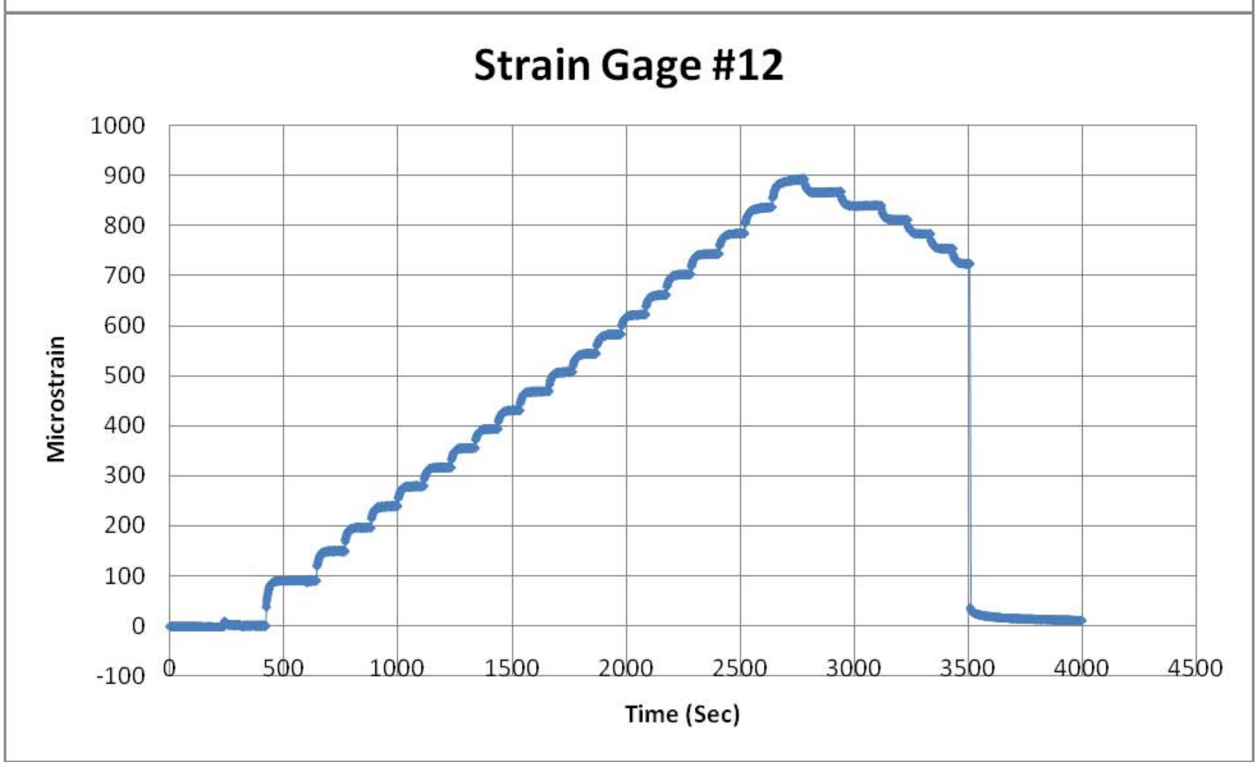
TOP VIEW

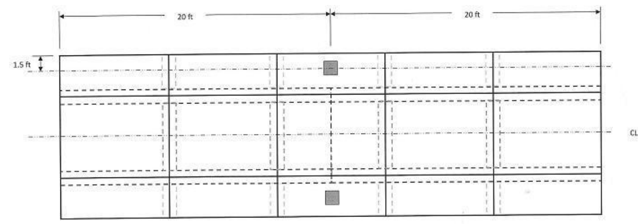
								-0.549	Relative to the Bridge					
							x	-0.7365	Relative to the Ground					
							x	-0.1875						
x			x		x		x	-0.1955			x			x
			-0.14875		-0.17663						-0.12125			

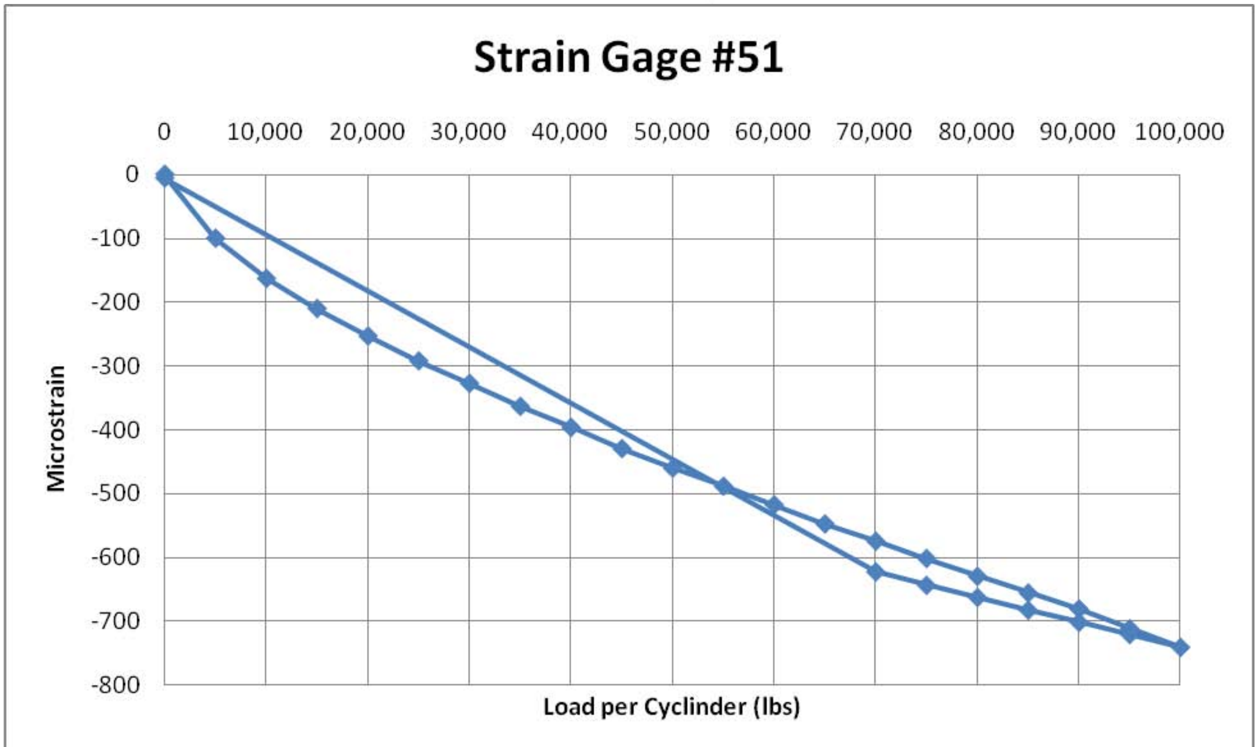
DEFLECTION

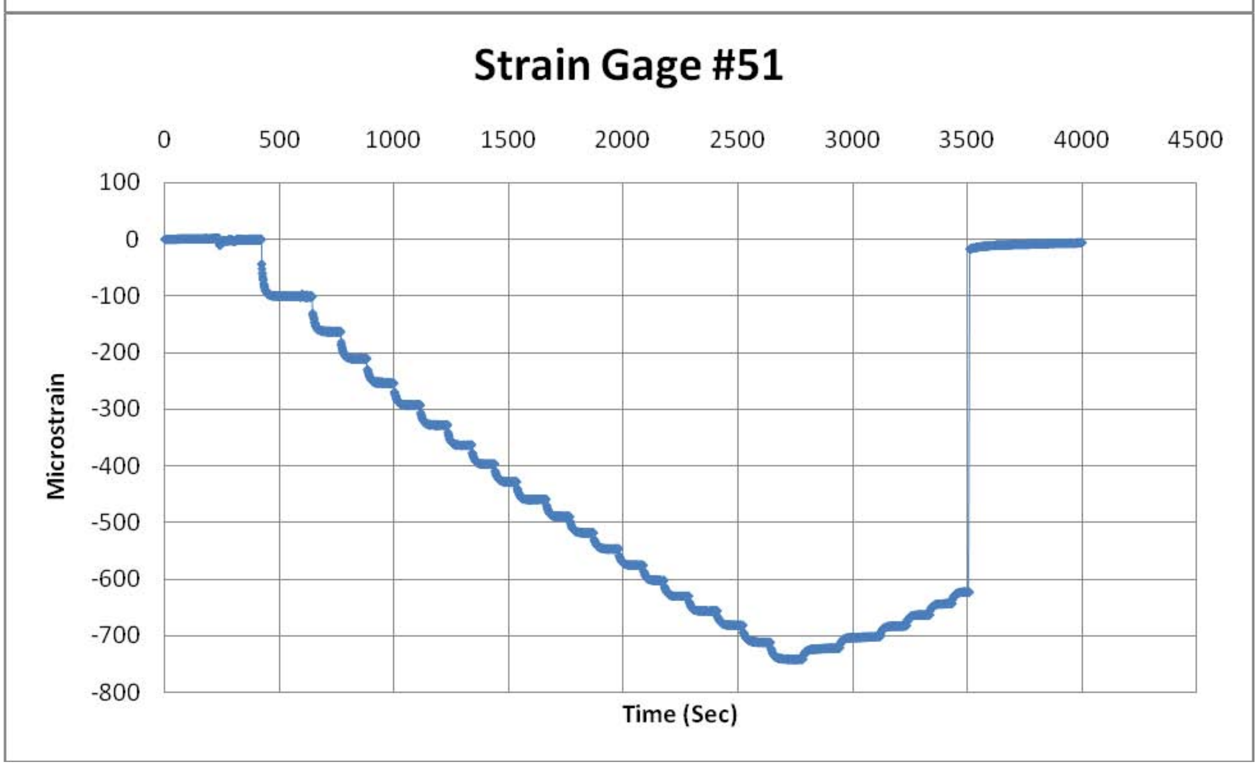

20 ft
20 ft
1.5 ft
CL

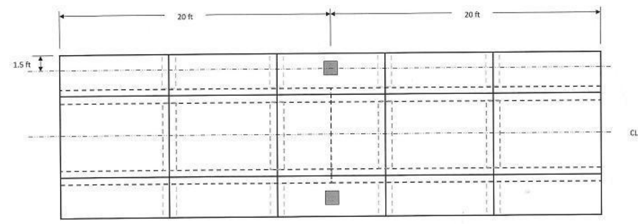

Strain Gage #12
Microstrain
Load per Cyclinder (lbs)
0
100
200
300
400
500
600
700
800
900
1000
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000

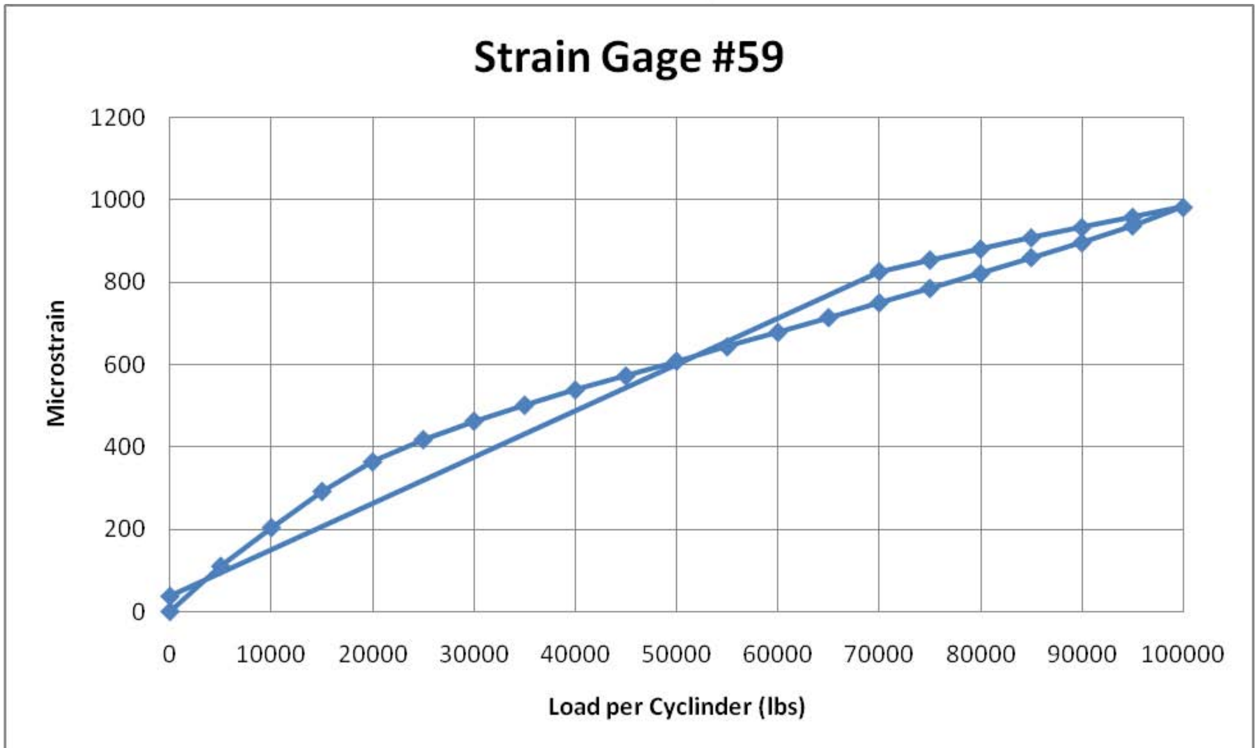

Strain Gage #12
Microstrain
Time (Sec)
-100
0
100
200
300
400
500
600
700
800
900
1000
0
500
1000
1500
2000
2500
3000
3500
4000
4500

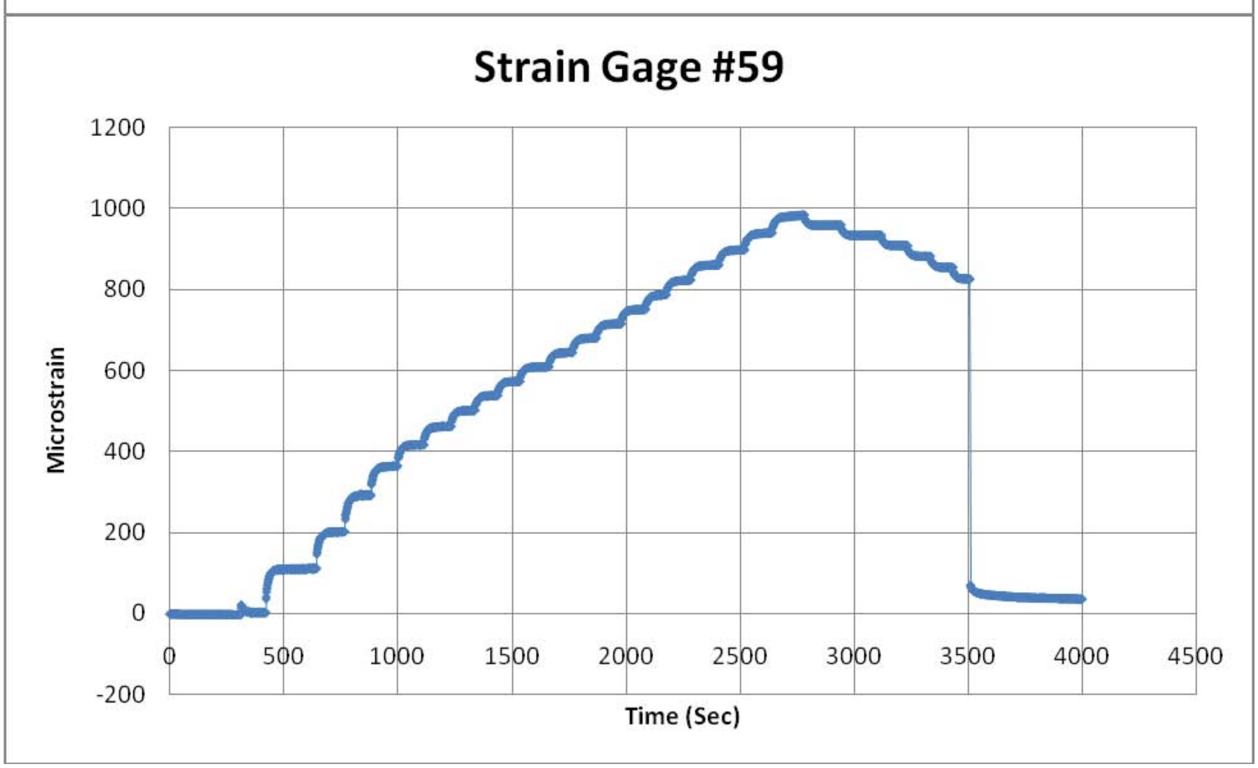

20 ft
20 ft
1.5 ft
CL


Strain Gage #51
Microstrain
Load per Cyclinder (lbs)

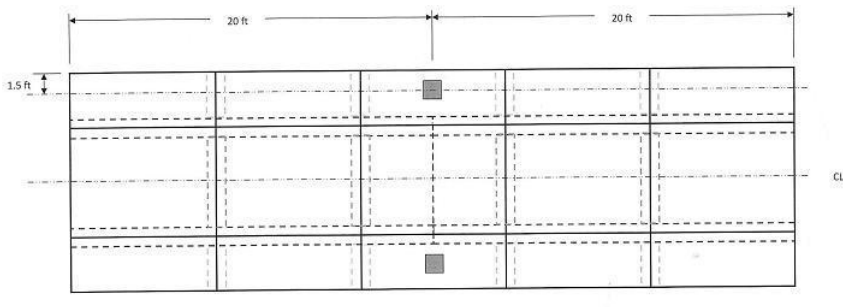

Strain Gage #51
Microstrain
Time (Sec)


20 ft
20 ft
1.5 ft
CL

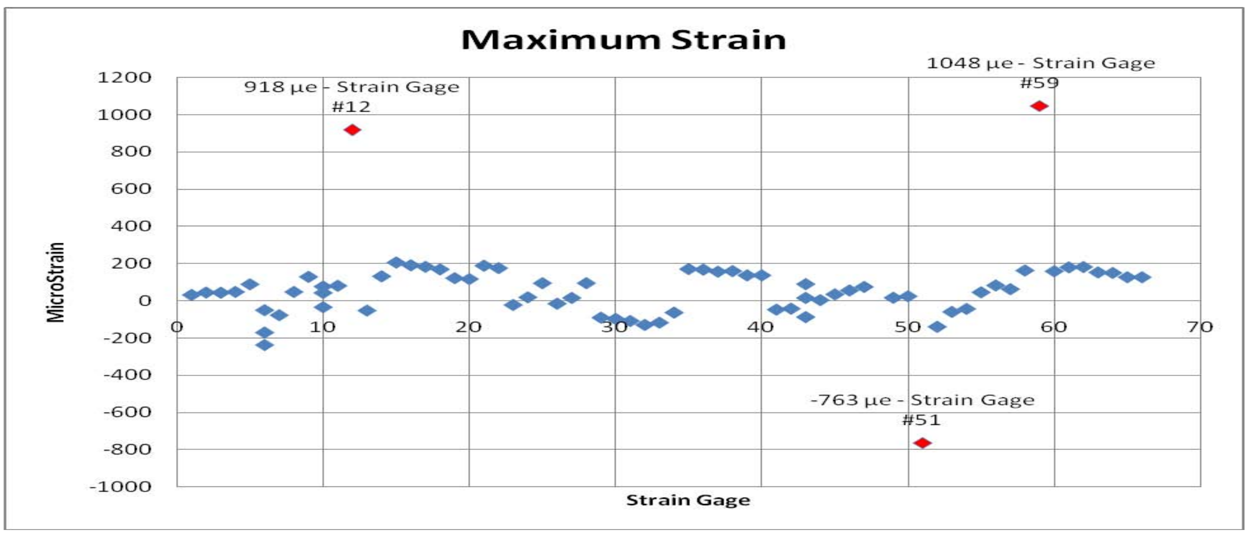

Strain Gage #59
Microstrain
Load per Cyclinder (lbs)
0
200
400
600
800
1000
1200
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000

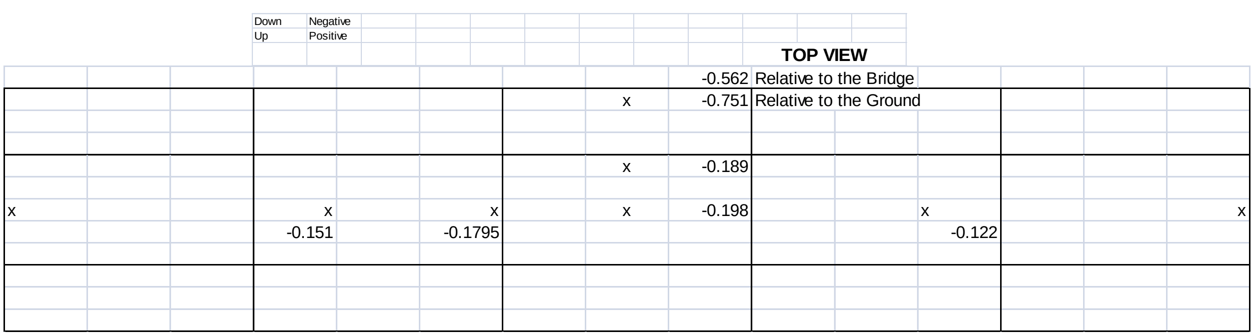

Strain Gage #59
Microstrain
Time (Sec)
-200
0
200
400
600
800
1000
1200
0
500
1000
1500
2000
2500
3000
3500
4000
4500

TEST#5

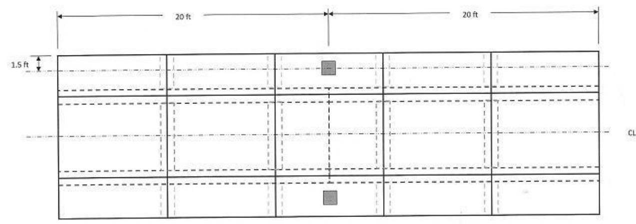


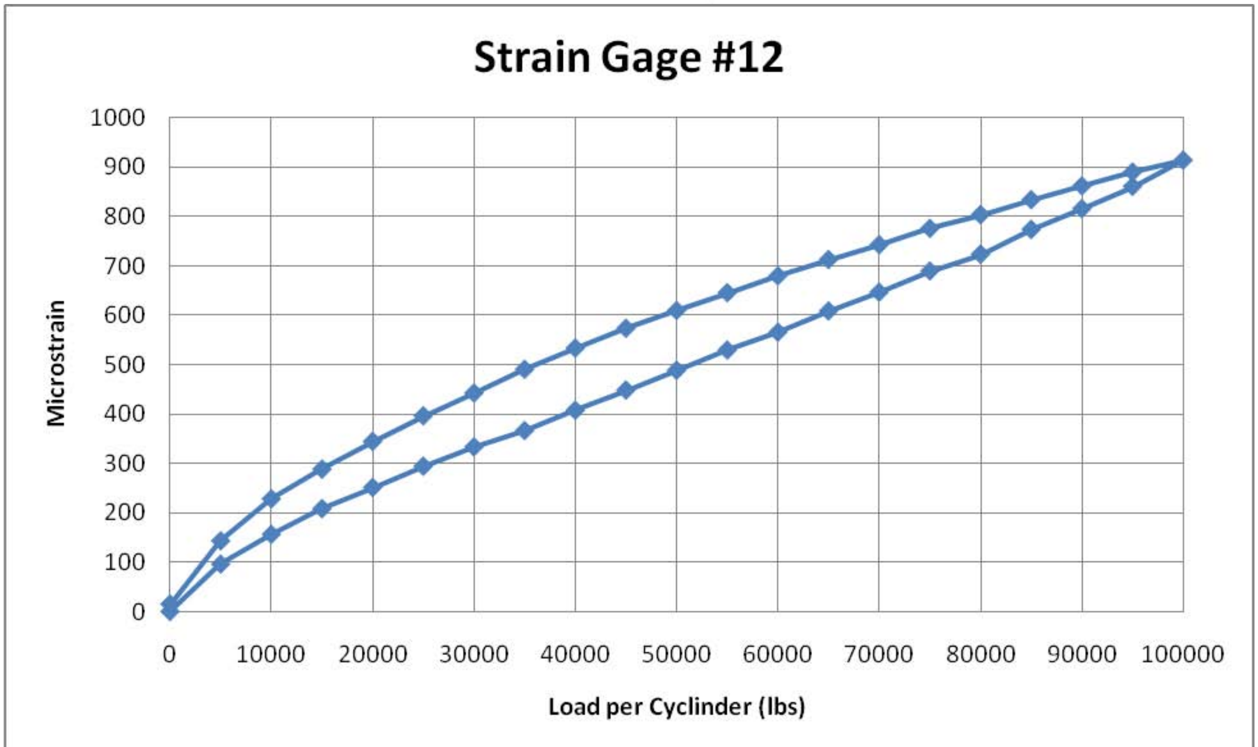
LOAD POSITIONS - 100,000 lbs./pad

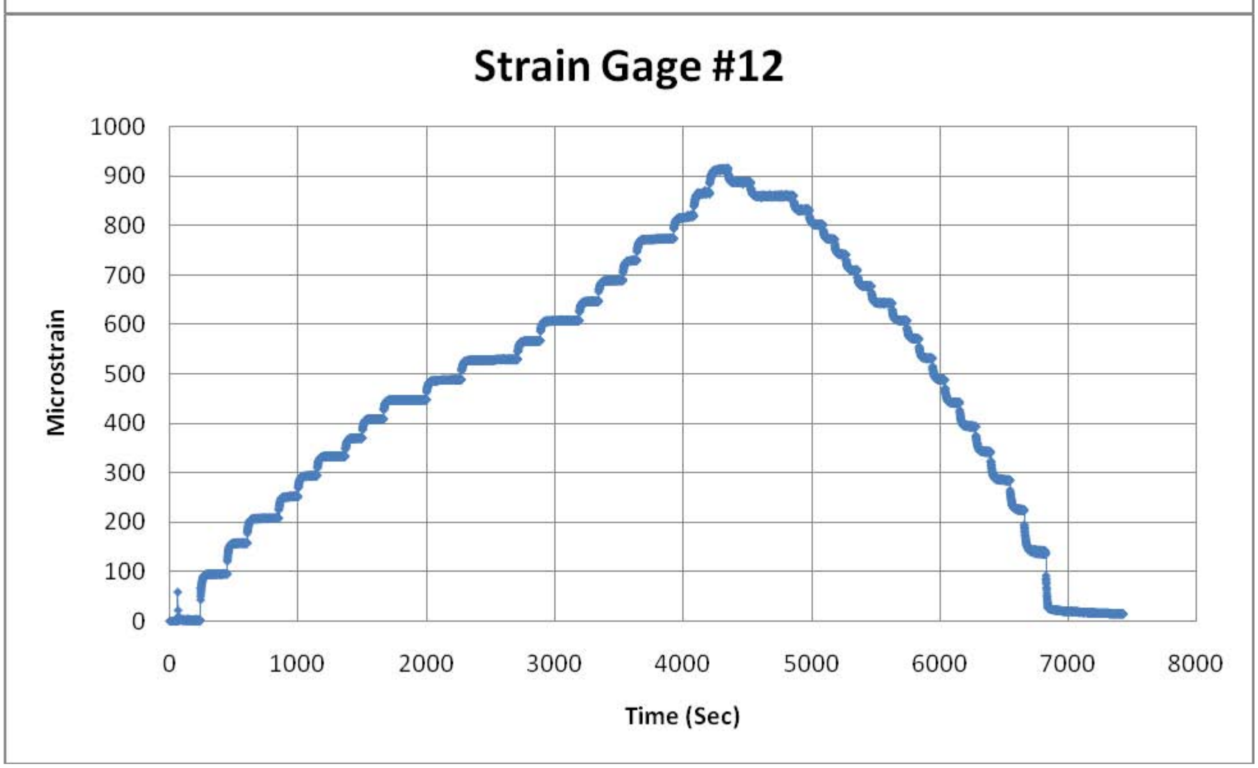


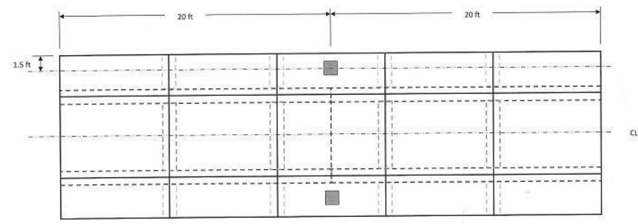


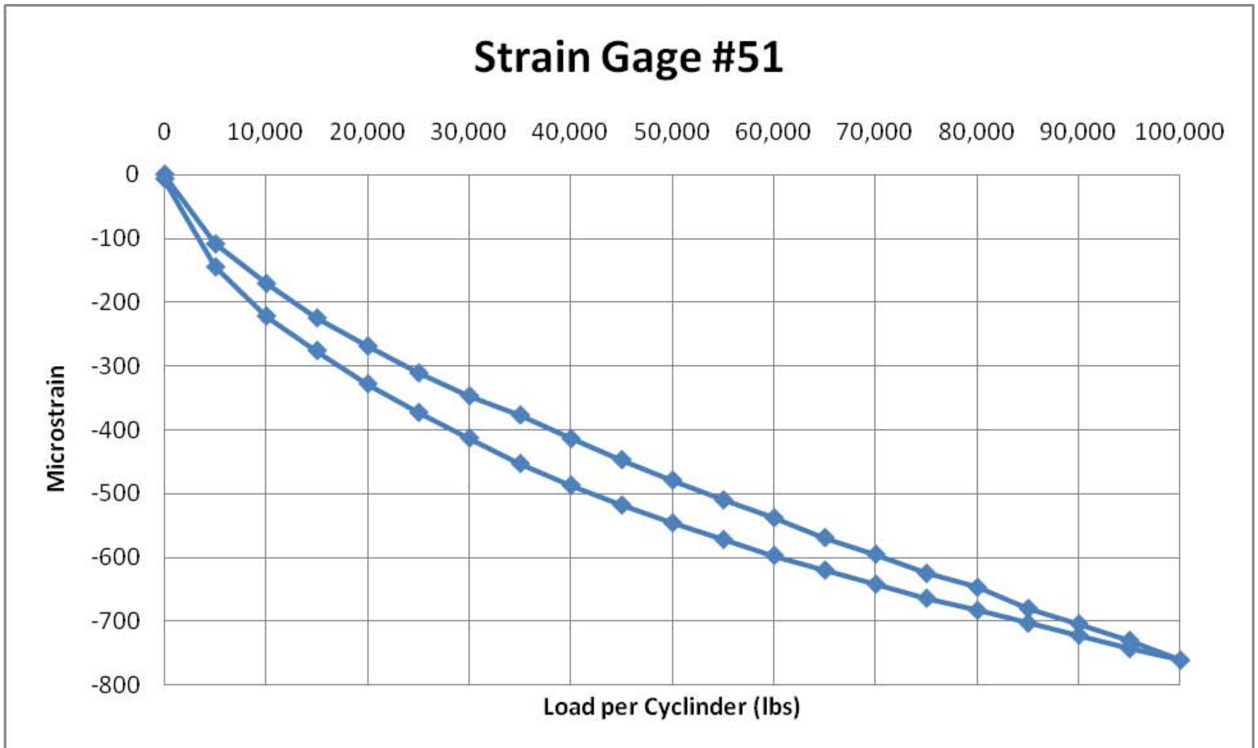
DEFLECTION

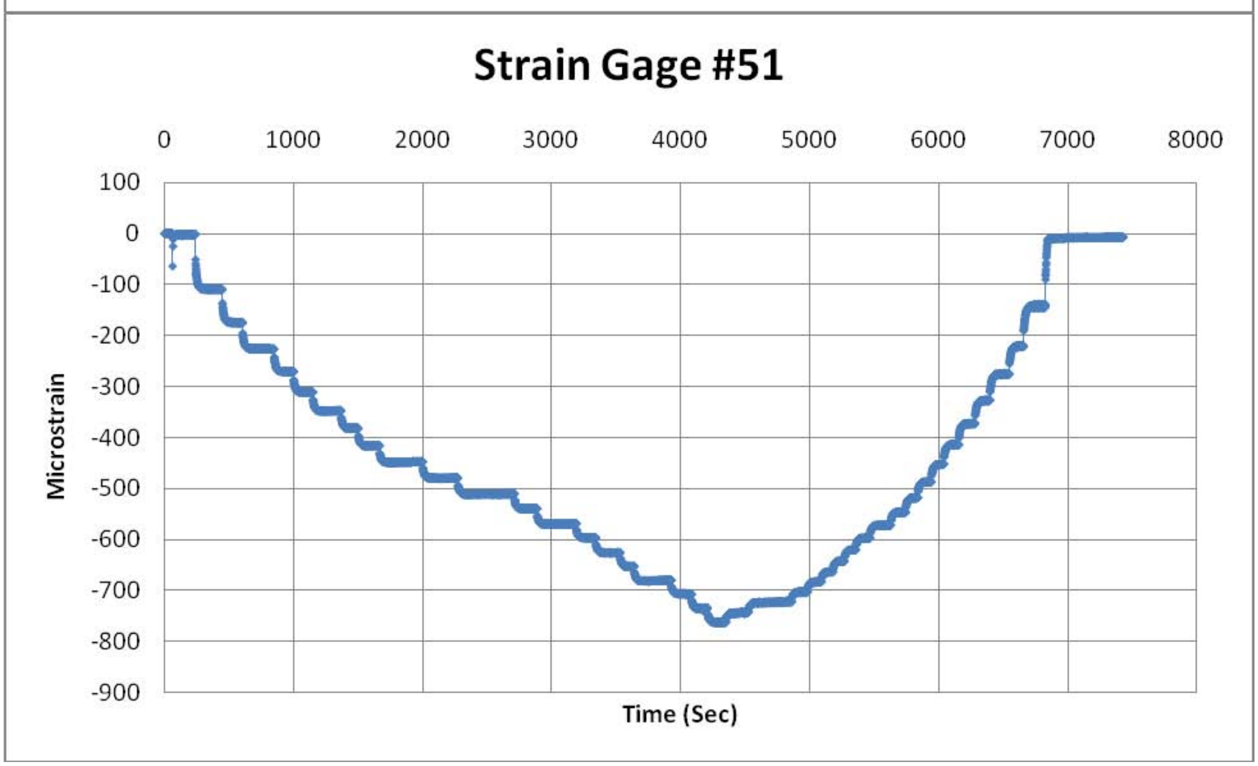

20 ft
20 ft
1.5 ft
CL

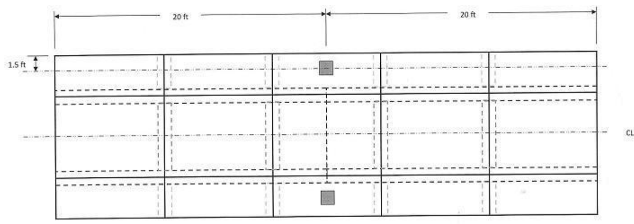

Strain Gage #12
Microstrain
0
100
200
300
400
500
600
700
800
900
1000
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
Load per Cyclinder (lbs)

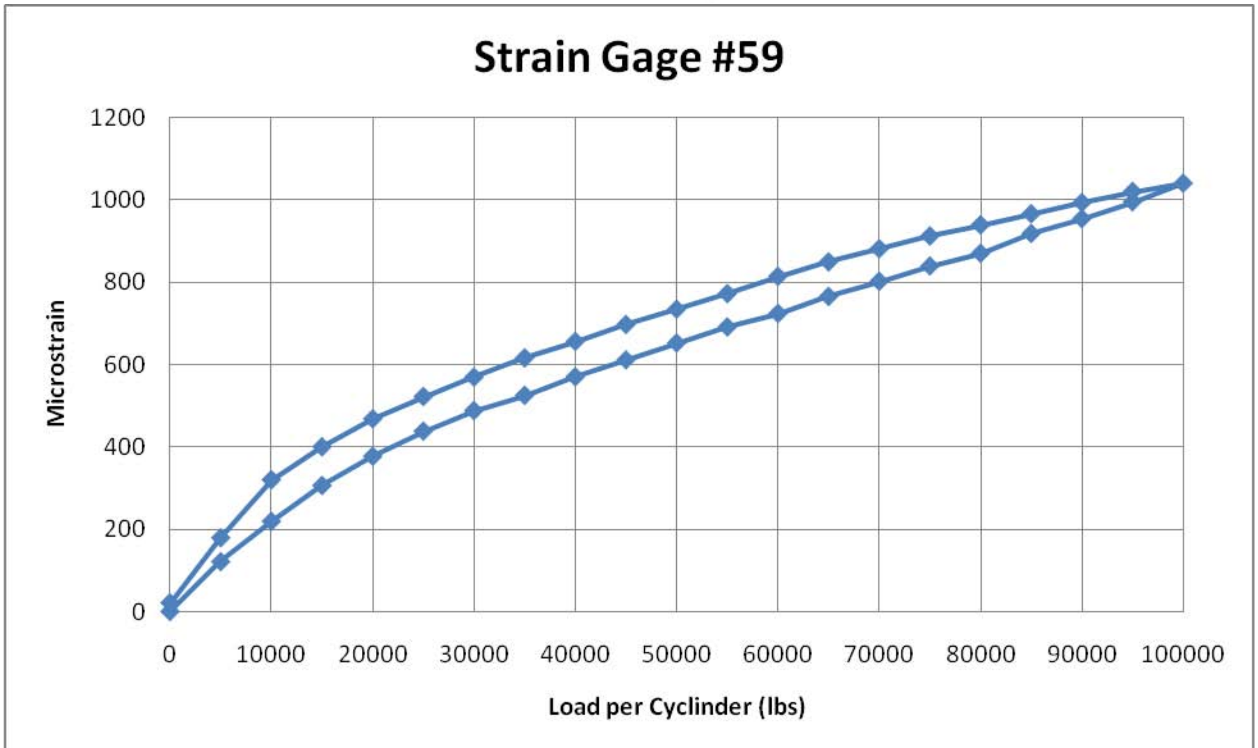

Strain Gage #12
Microstrain
0
100
200
300
400
500
600
700
800
900
1000
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (Sec)

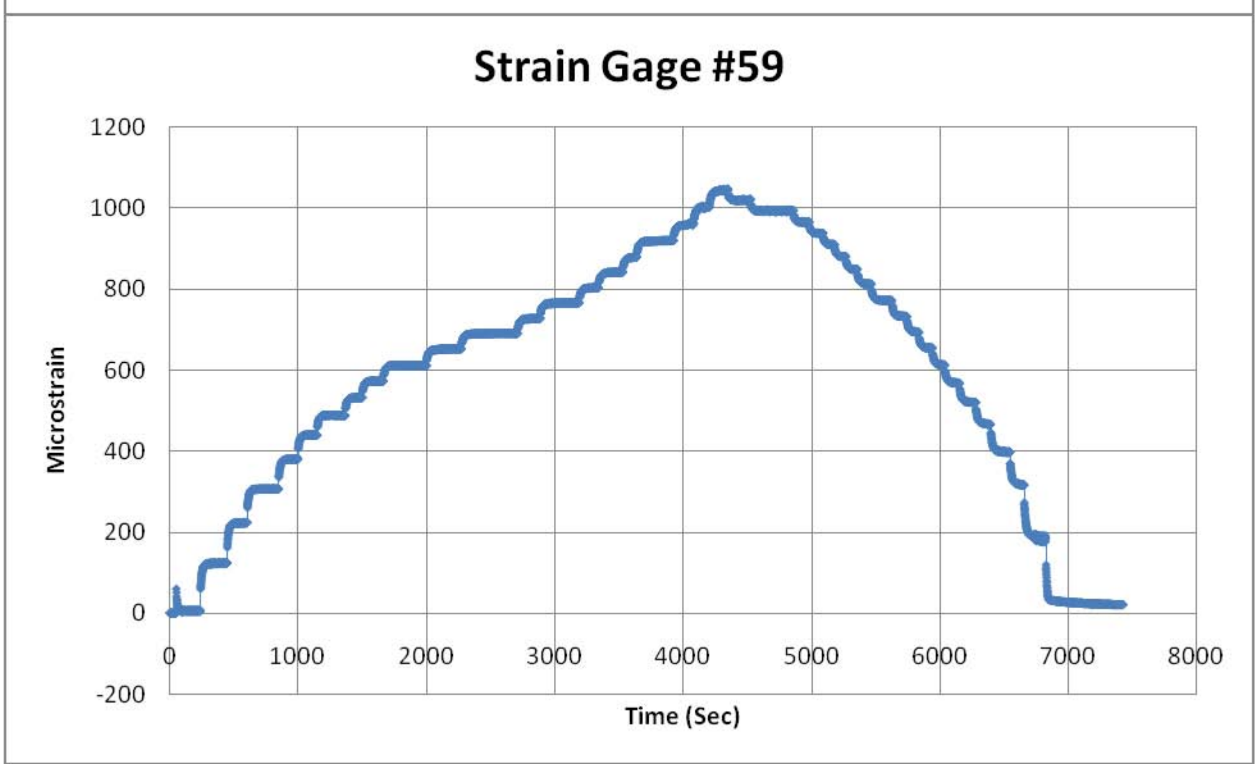

20 ft
20 ft
1.5 ft
CL


Strain Gage #51
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
0
-100
-200
-300
-400
-500
-600
-700
-800
Microstrain
Load per Cyclinder (lbs)

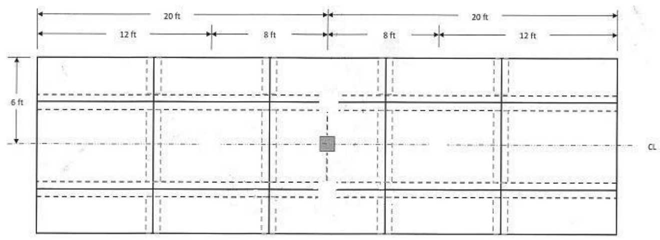

Strain Gage #51
0
1000
2000
3000
4000
5000
6000
7000
8000
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
Microstrain
Time (Sec)


20 ft
20 ft
1.5 ft
CL

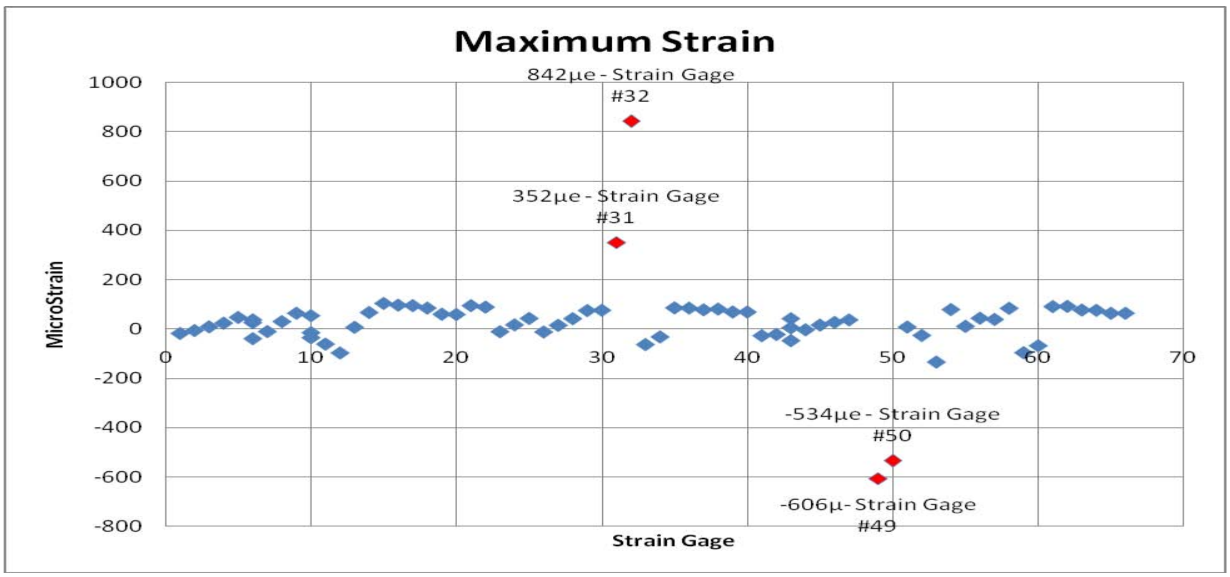

Strain Gage #59
Microstrain
Load per Cyclinder (lbs)
0
200
400
600
800
1000
1200
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000


Strain Gage #59
Microstrain
Time (Sec)
-200
0
200
400
600
800
1000
1200
0
1000
2000
3000
4000
5000
6000
7000
8000

TEST #6



LOAD POSITION - 100,000 lbs.

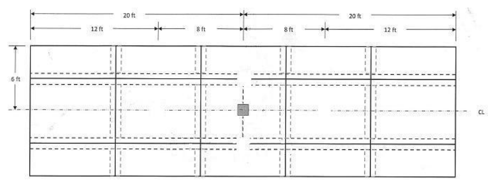


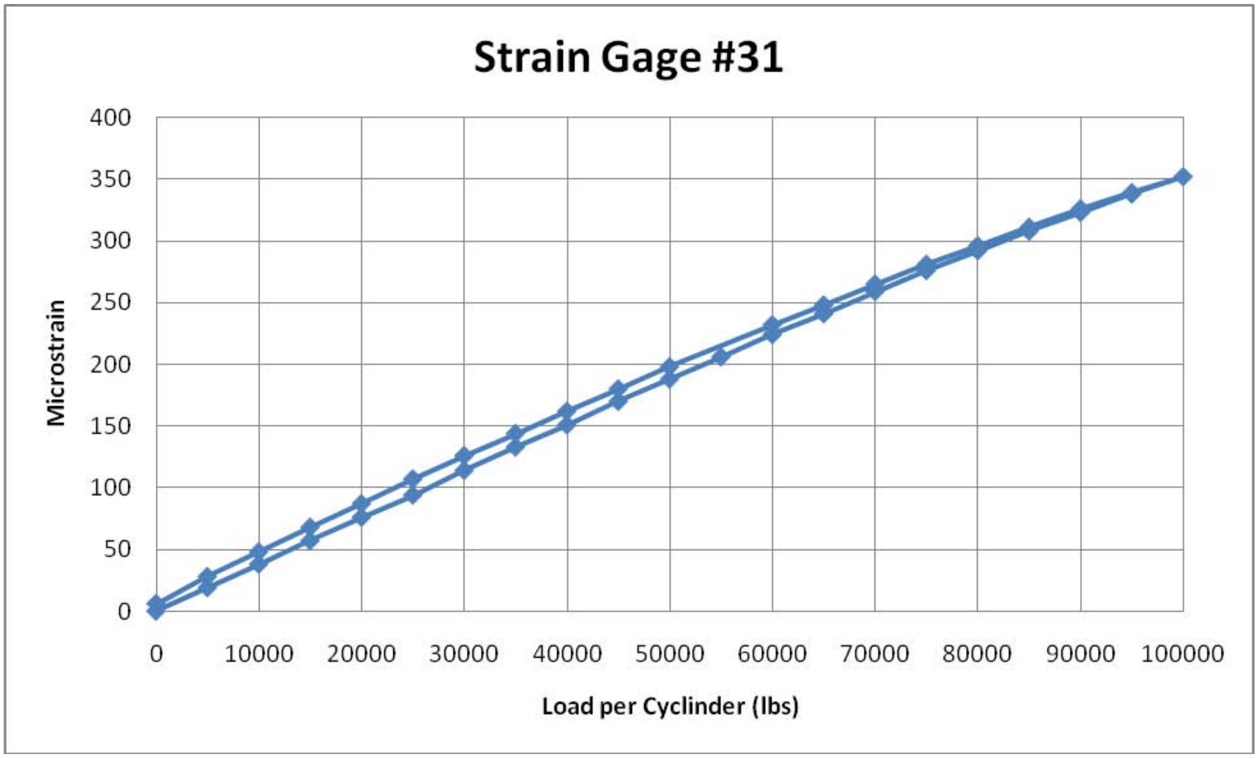
Down	Negative
Up	Positive

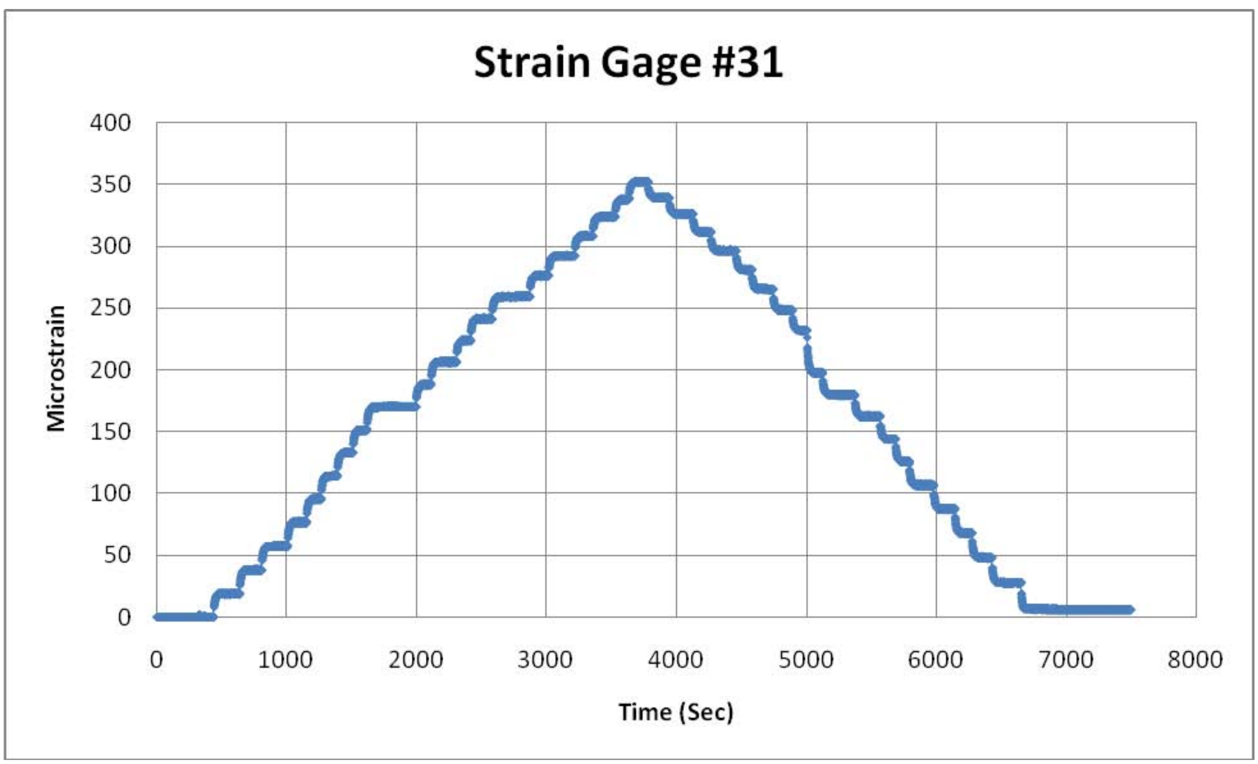
TOP VIEW

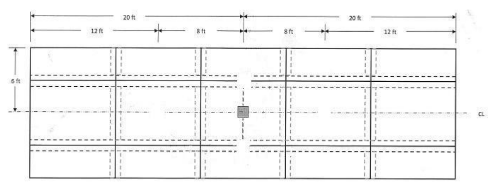
								0.054	Relative to the Bridge					
							x	-0.0415	Relative to the Ground					
							x	-0.0955						
x			x		x		x	-0.0965			x			x
			-0.07575		-0.09063						-0.06325			

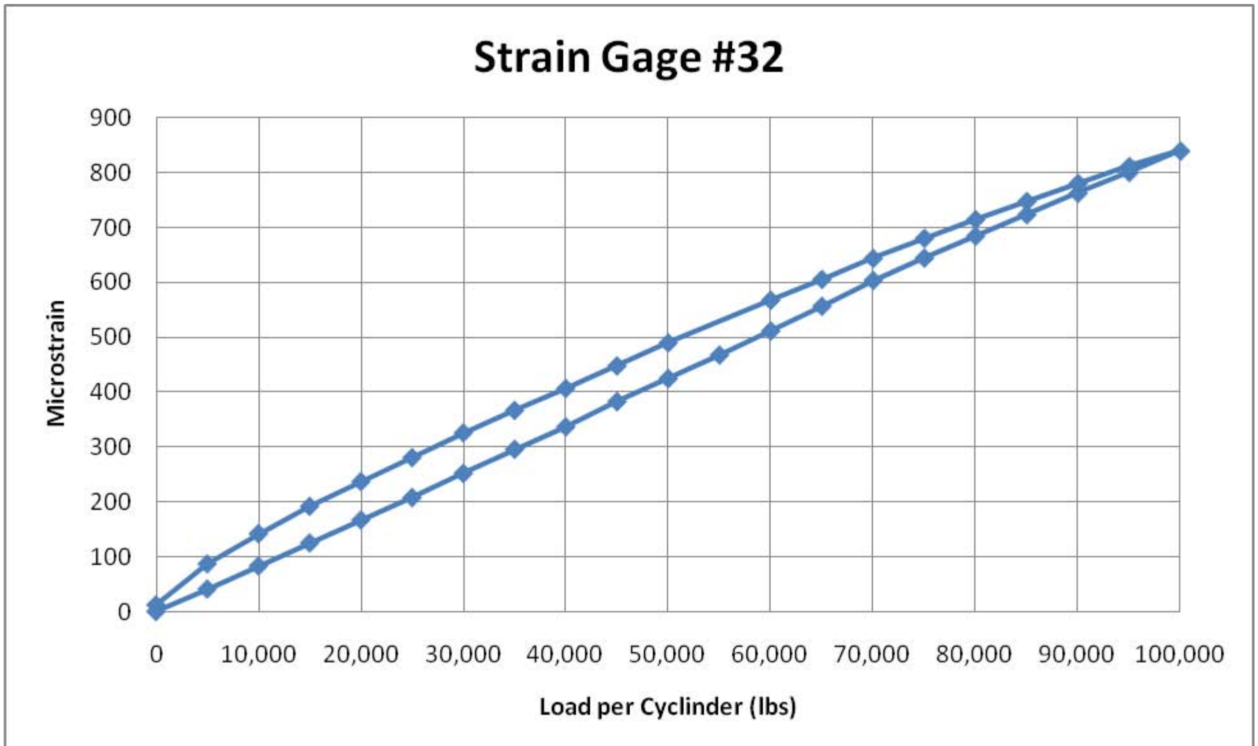
DEFLECTION

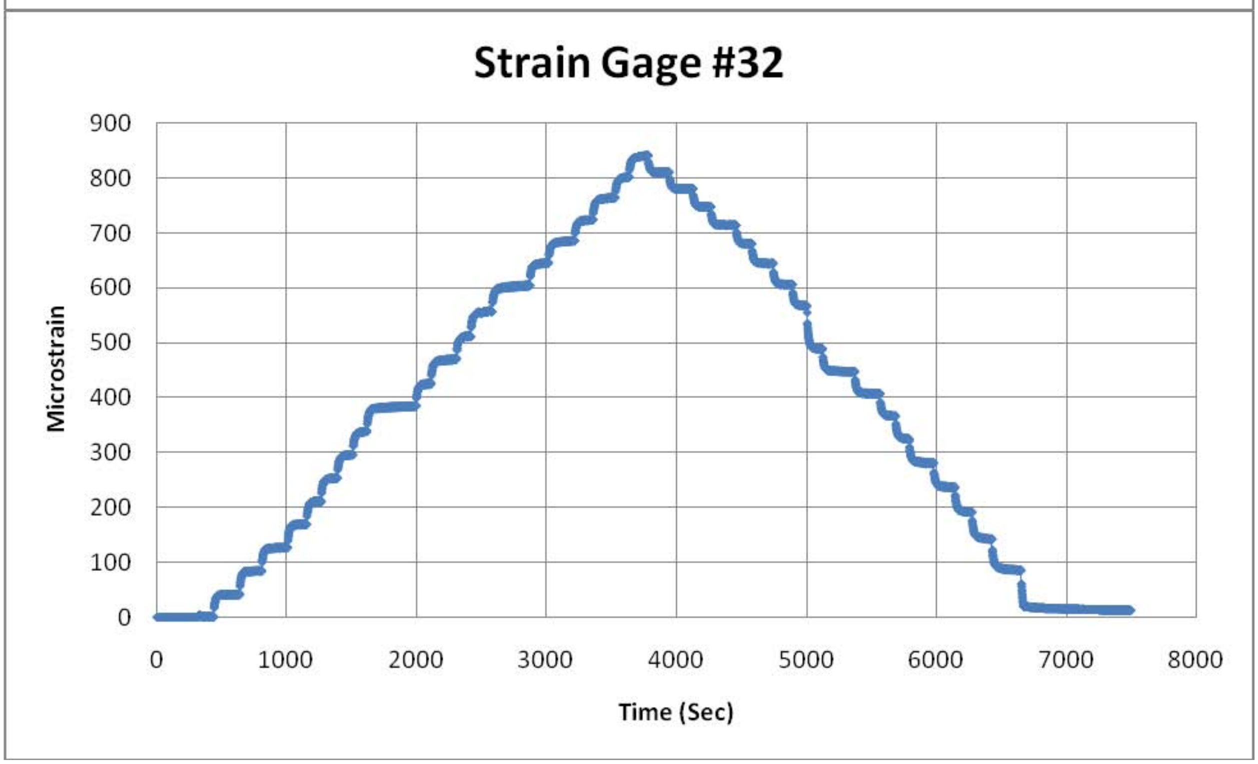


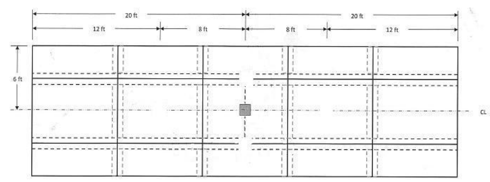

Strain Gage #31
Microstrain
Load per Cyclinder (lbs)
0
50
100
150
200
250
300
350
400
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000

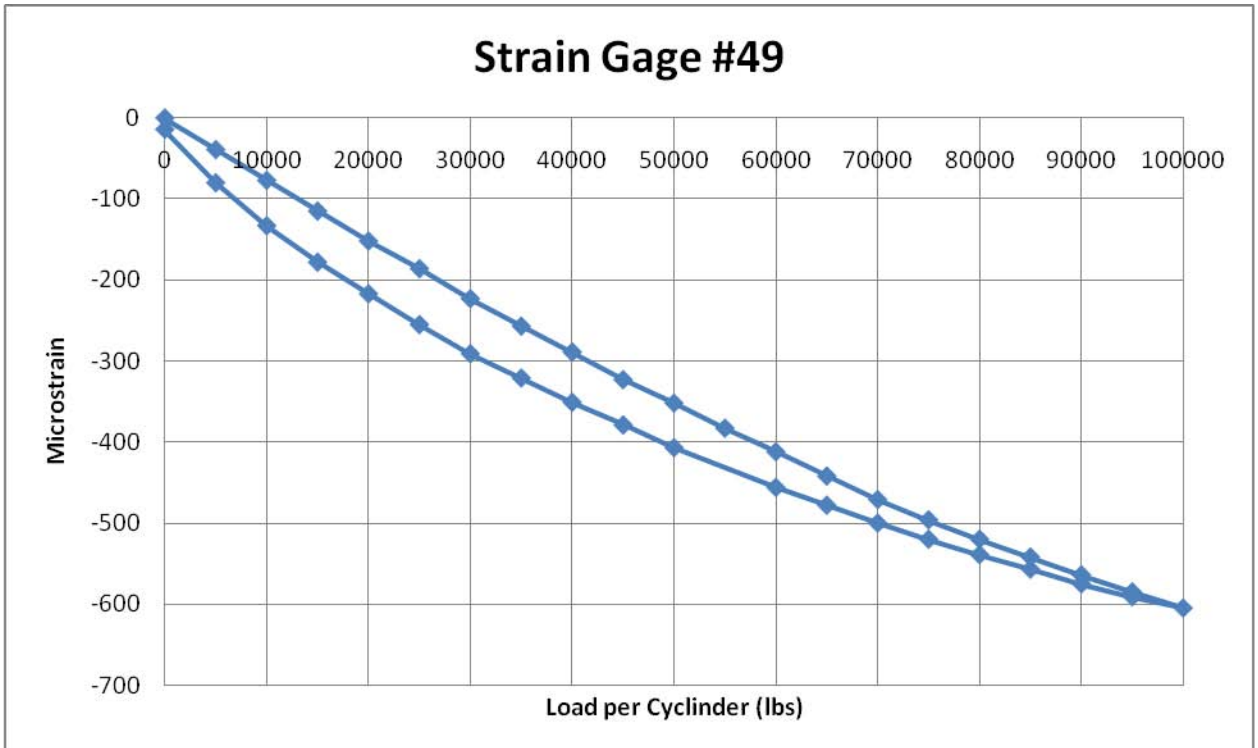

Strain Gage #31
Microstrain
Time (Sec)
0
50
100
150
200
250
300
350
400
0
1000
2000
3000
4000
5000
6000
7000
8000

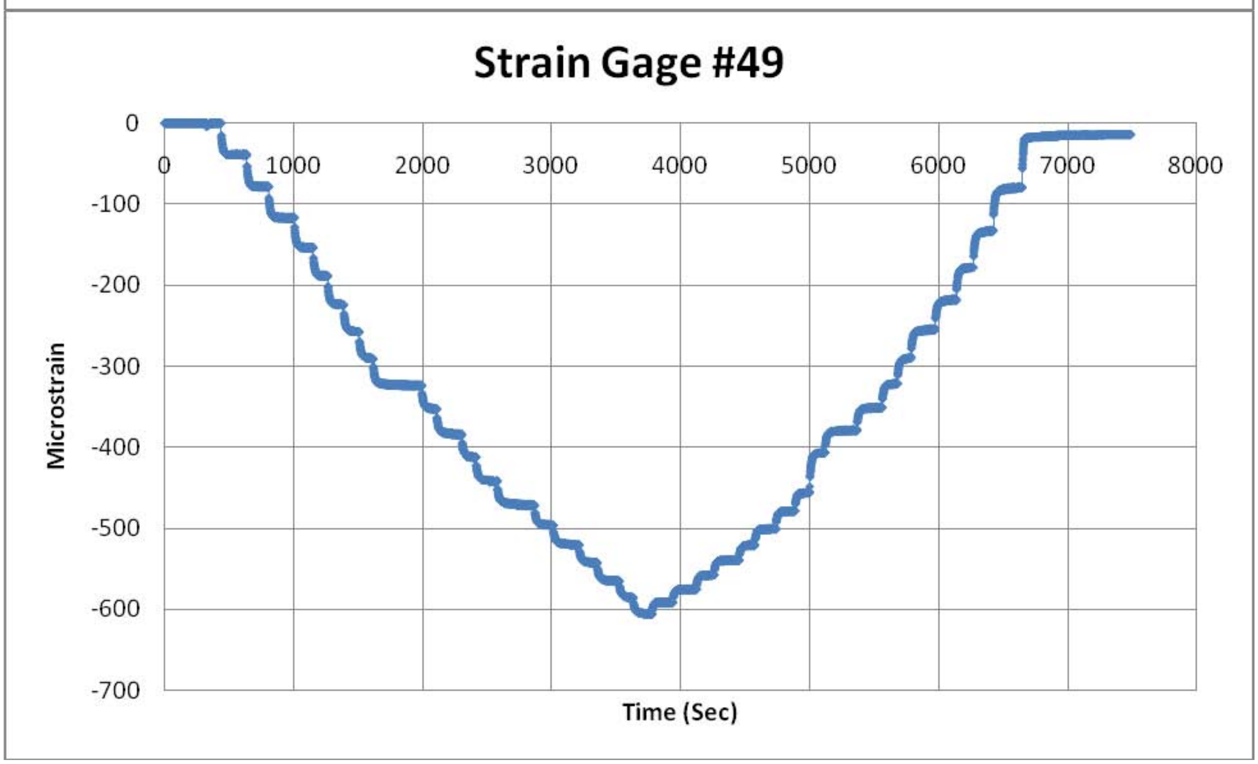


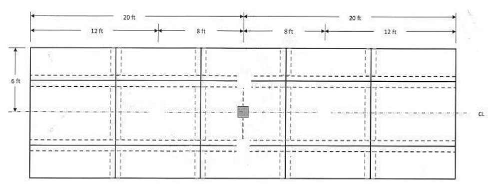

Strain Gage #32
Microstrain
Load per Cyclinder (lbs)

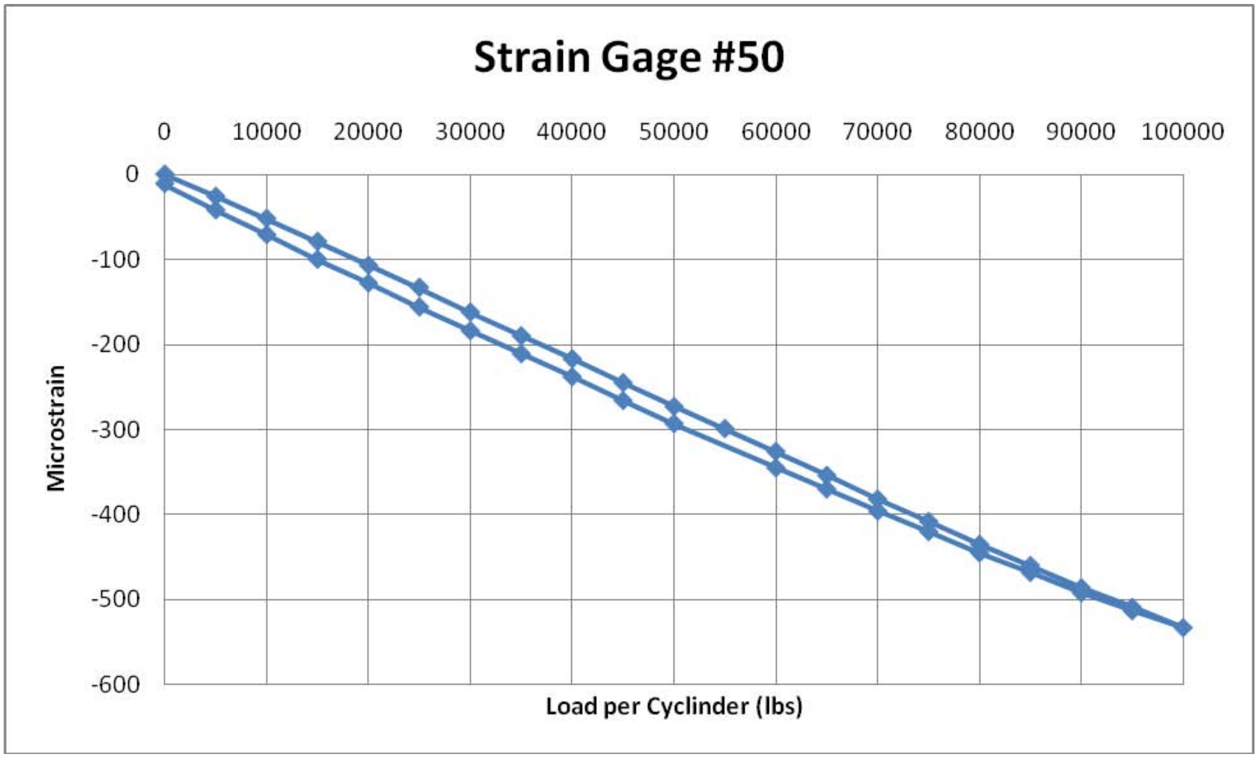

Strain Gage #32
Microstrain
Time (Sec)

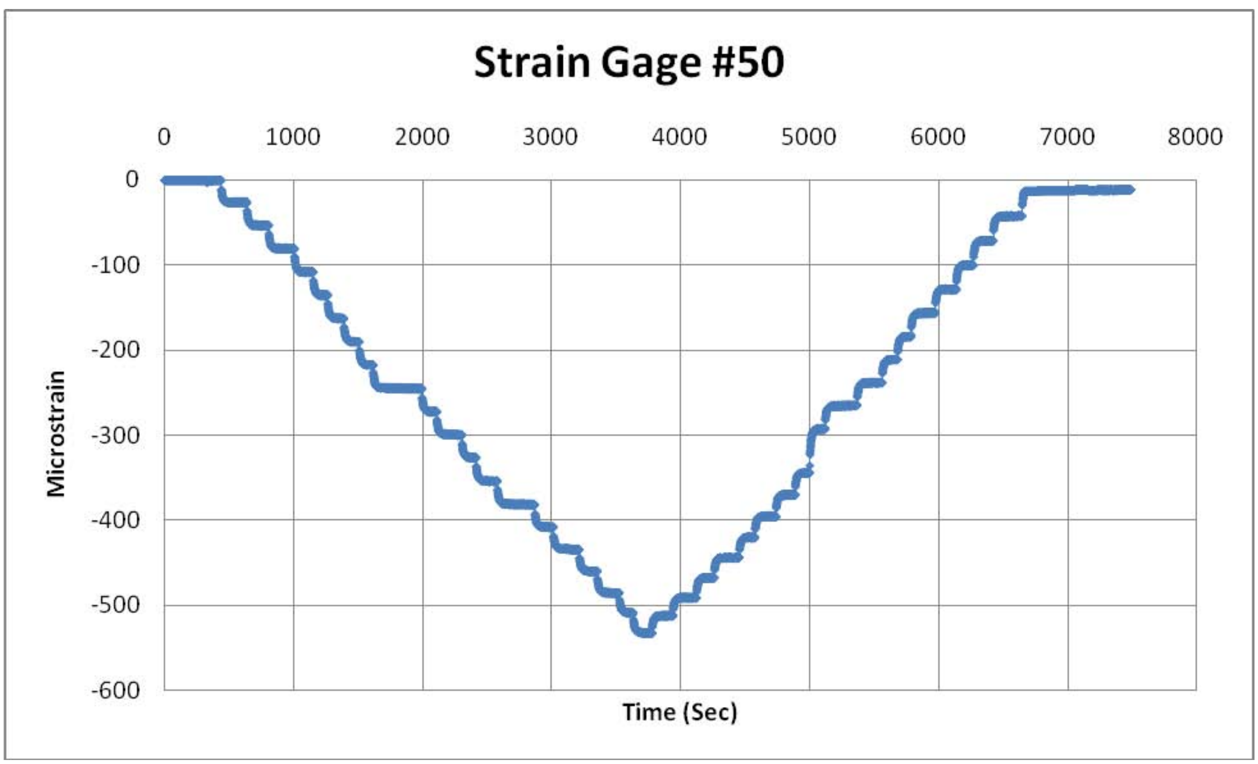



Strain Gage #49
Microstrain
Load per Cyclinder (lbs)
0
-100
-200
-300
-400
-500
-600
-700
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000

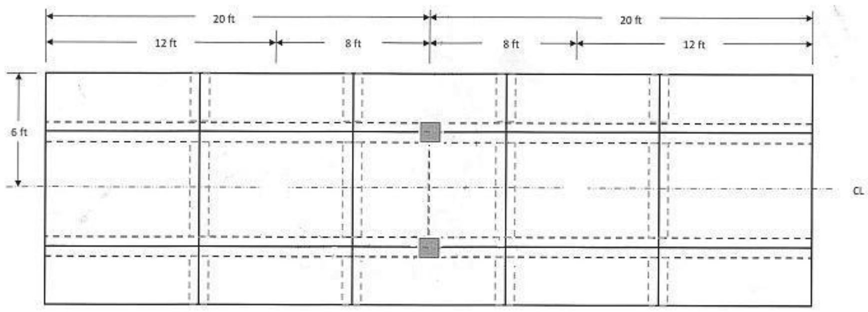

Strain Gage #49
Microstrain
Time (Sec)
0
-100
-200
-300
-400
-500
-600
-700
0
1000
2000
3000
4000
5000
6000
7000
8000


20 ft
20 ft
12 ft
8 ft
8 ft
12 ft
6 ft
CL

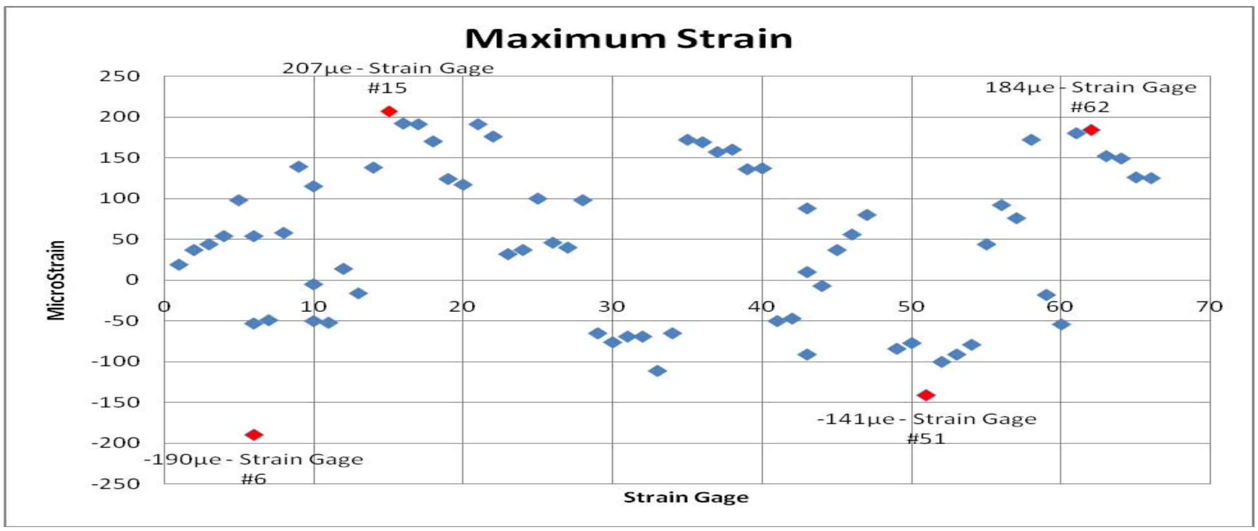

Strain Gage #50
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
0
-100
-200
-300
-400
-500
-600
Microstrain
Load per Cyclinder (lbs)

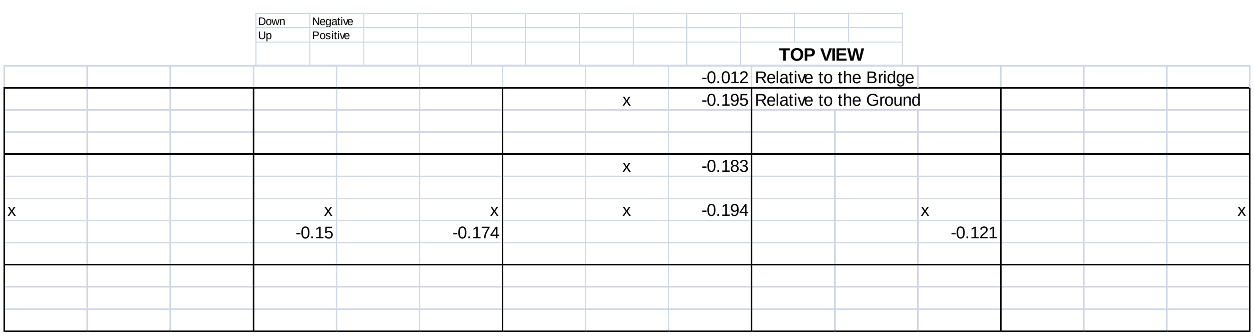

Strain Gage #50
0
1000
2000
3000
4000
5000
6000
7000
8000
0
-100
-200
-300
-400
-500
-600
Microstrain
Time (Sec)

TEST#7

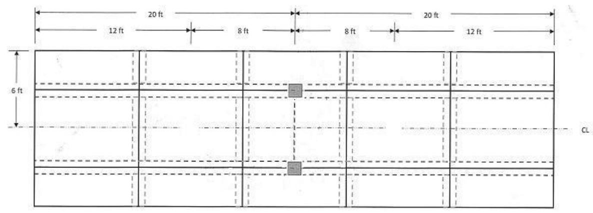


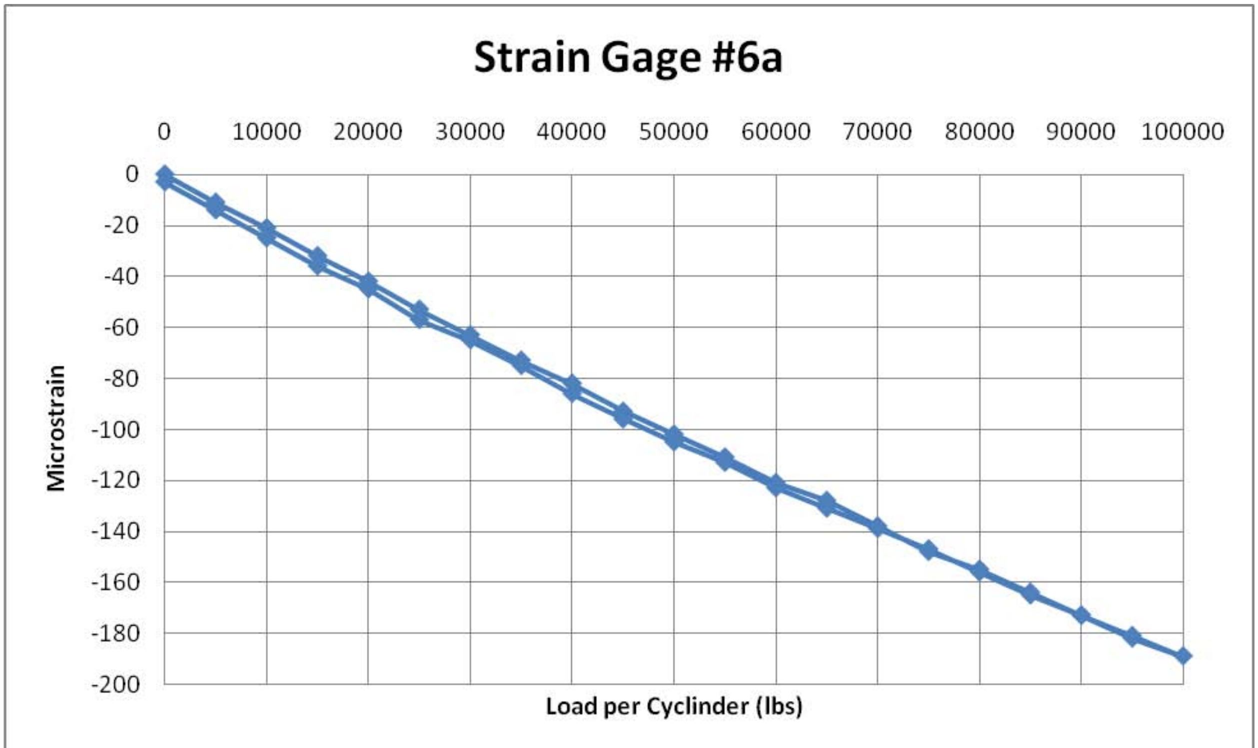
LOAD POSITIONS - 100,000 lbs./pad

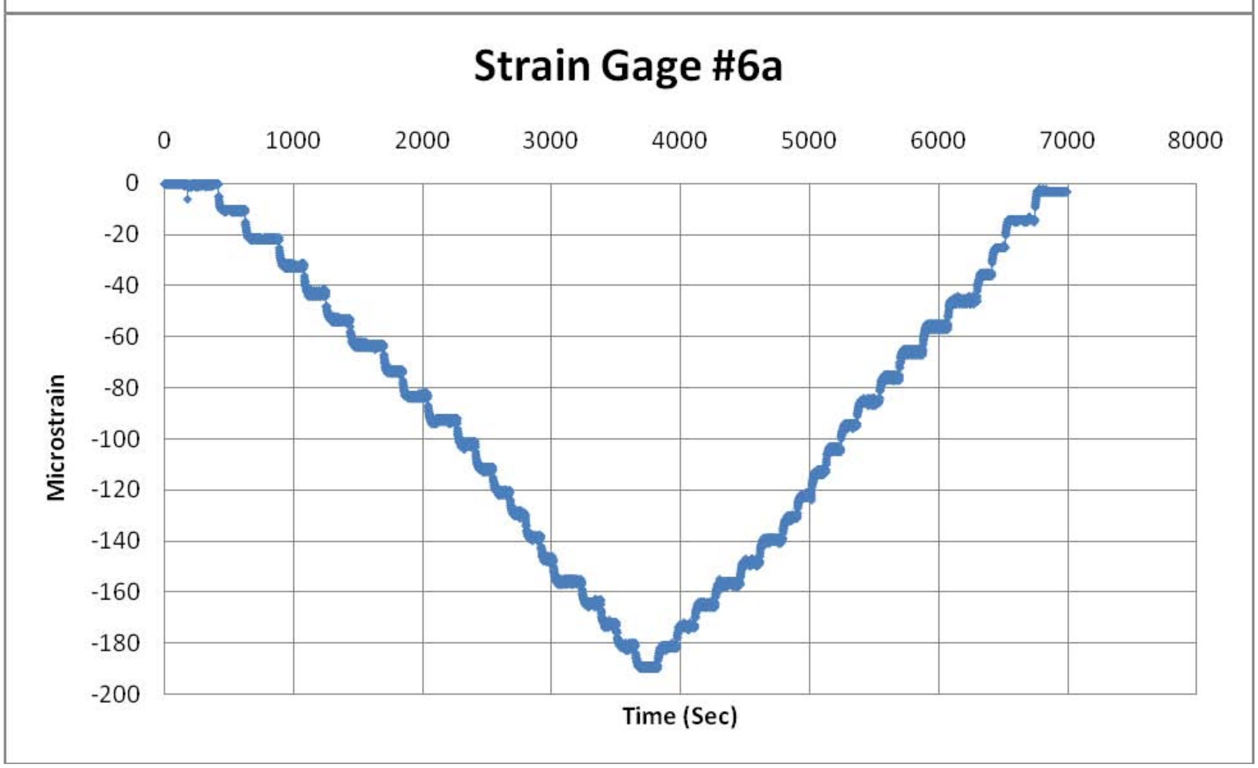


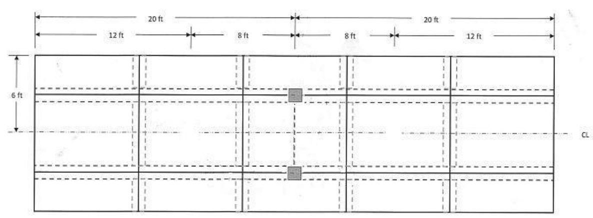


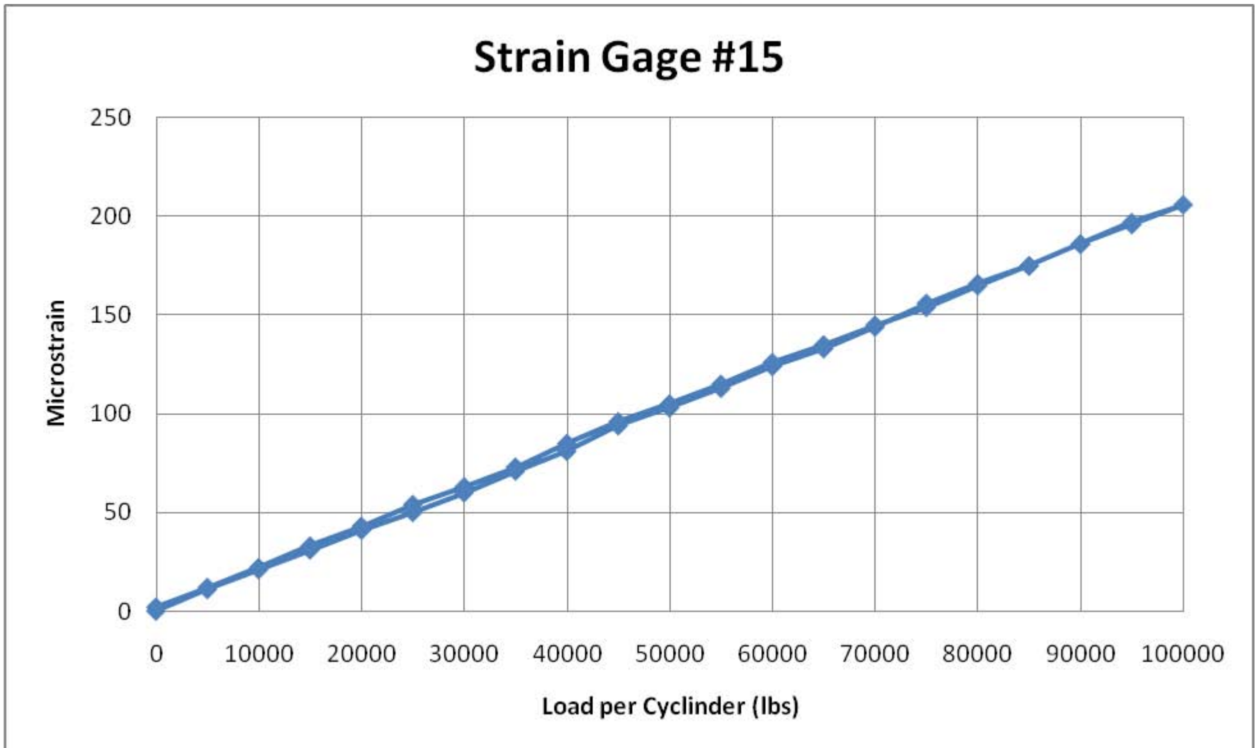
DEFLECTION

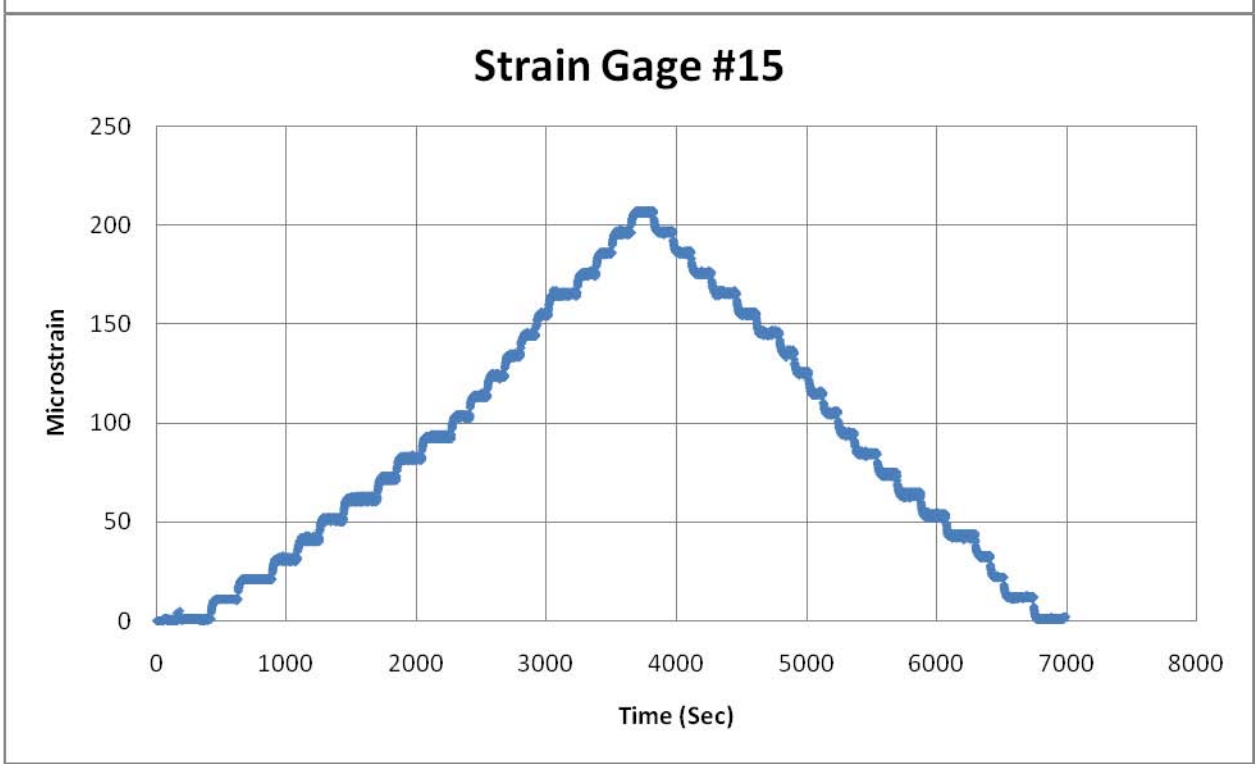

20 ft
20 ft
12 ft
8 ft
8 ft
12 ft
6 ft
CL

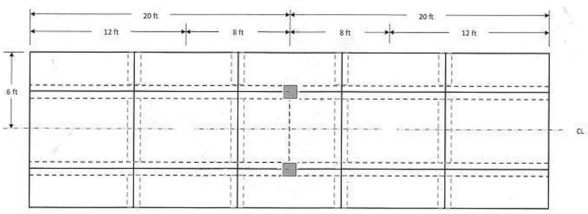

Strain Gage #6a
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
Microstrain
Load per Cyclinder (lbs)

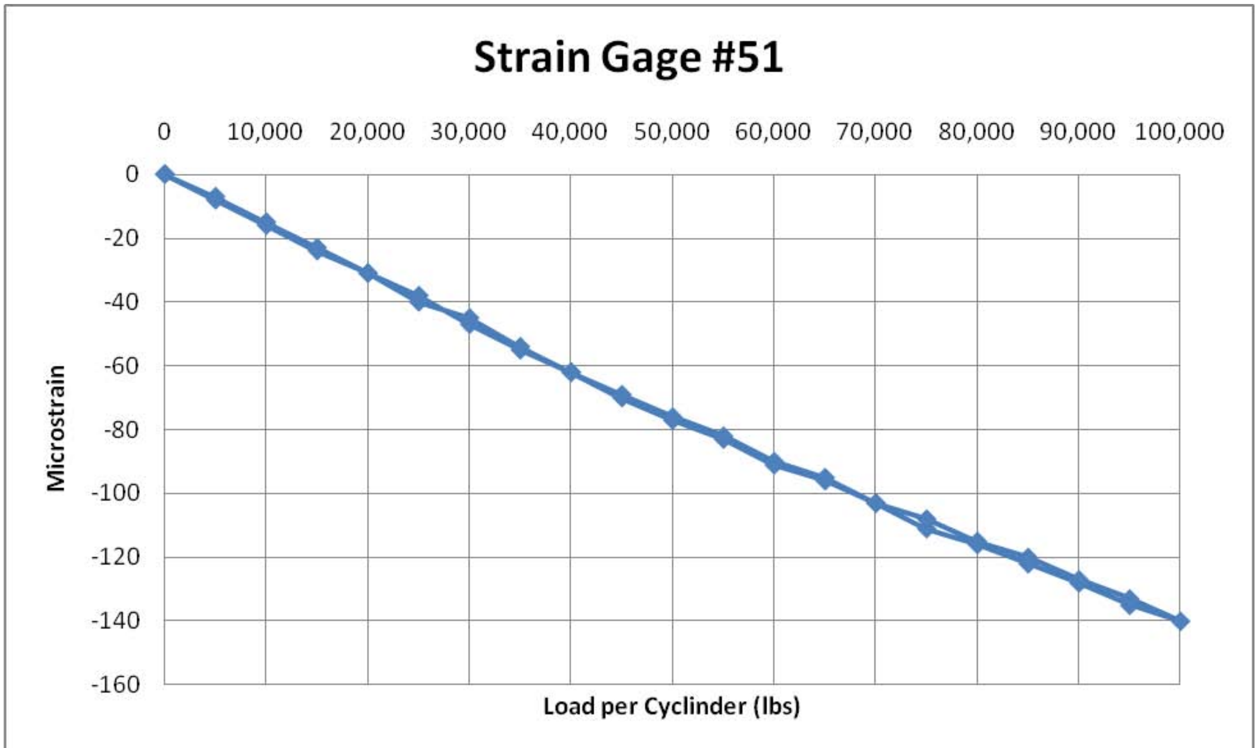

Strain Gage #6a
0
1000
2000
3000
4000
5000
6000
7000
8000
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
Microstrain
Time (Sec)

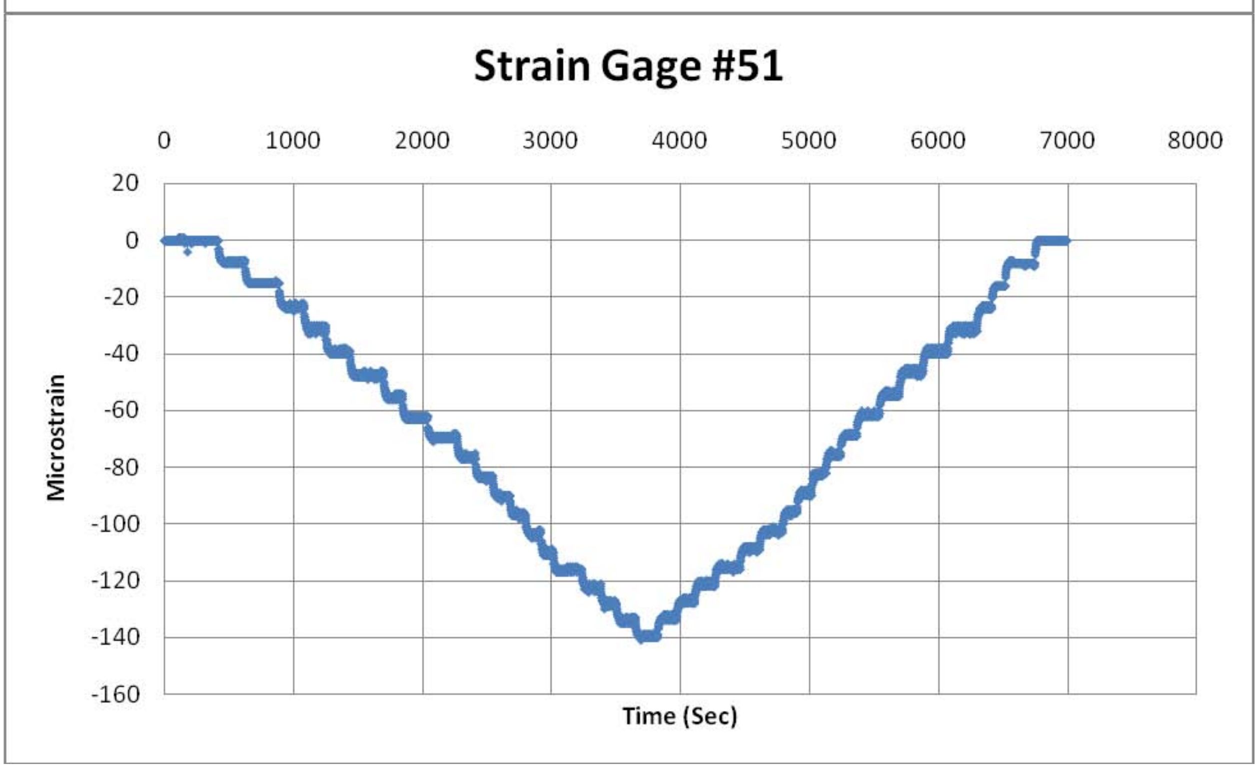

20 ft
20 ft
12 ft
8 ft
8 ft
12 ft
6 ft
CL

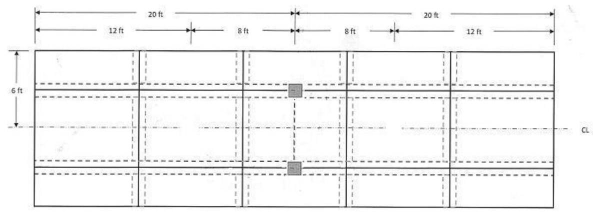

Strain Gage #15
Microstrain
250
200
150
100
50
0
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
Load per Cyclinder (lbs)

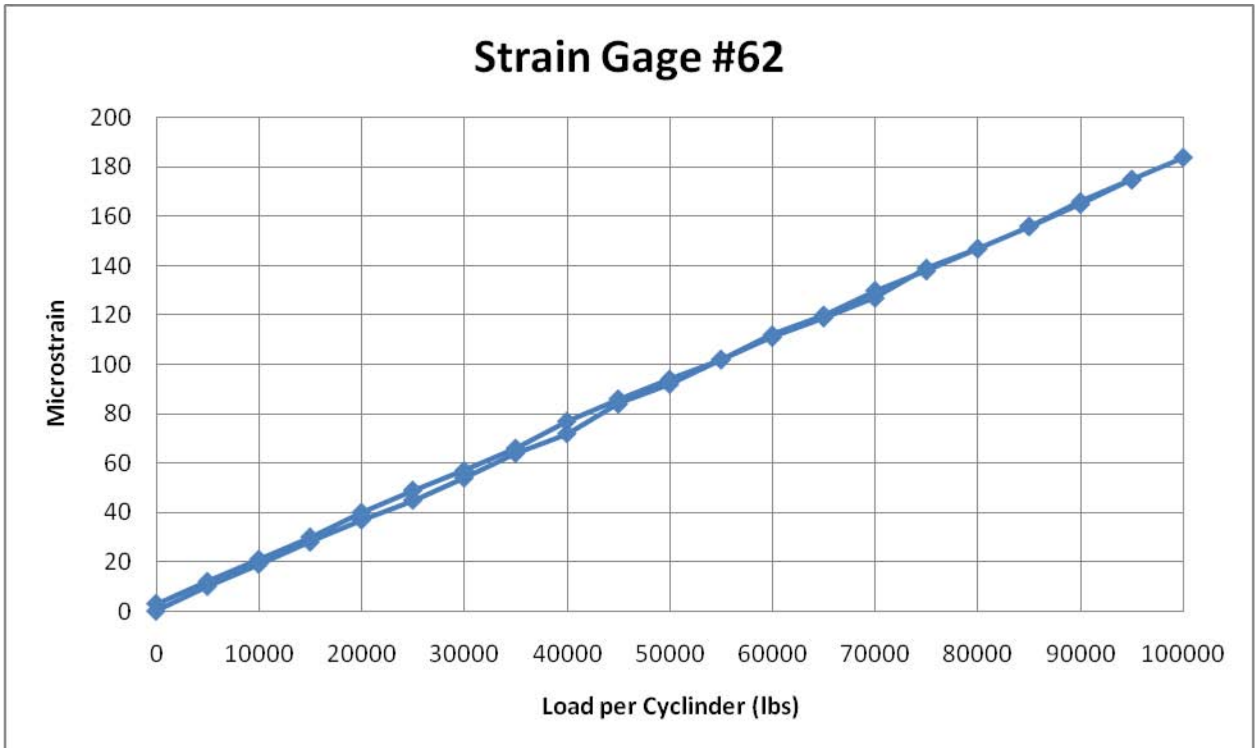

Strain Gage #15
Microstrain
250
200
150
100
50
0
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (Sec)

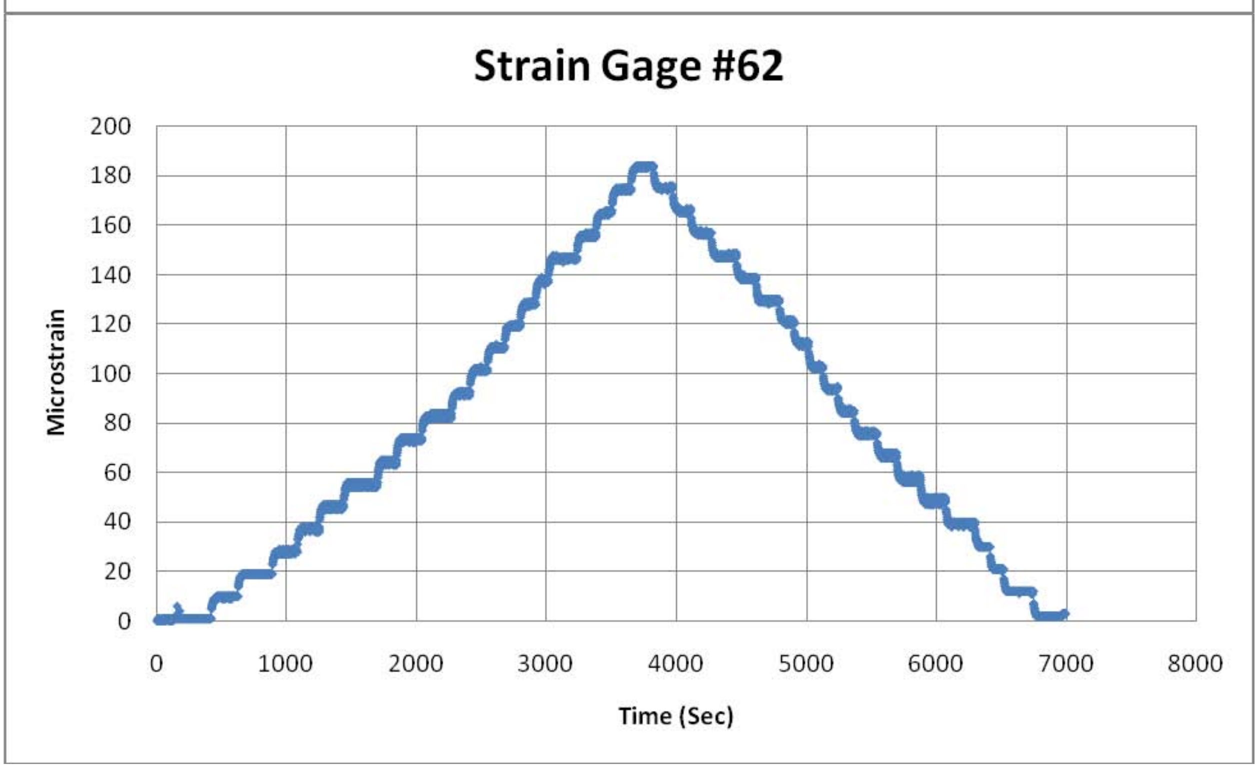

20 ft
20 ft
12 ft
8 ft
8 ft
12 ft
6 ft
CL


Strain Gage #51
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
0
-20
-40
-60
-80
-100
-120
-140
-160
Microstrain
Load per Cyclinder (lbs)


Strain Gage #51
0
1000
2000
3000
4000
5000
6000
7000
8000
20
0
-20
-40
-60
-80
-100
-120
-140
-160
Microstrain
Time (Sec)


20 ft
20 ft
12 ft
8 ft
8 ft
12 ft
6 ft
CL


Strain Gage #62
Microstrain
200
180
160
140
120
100
80
60
40
20
0
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
Load per Cyclinder (lbs)


Strain Gage #62
Microstrain
200
180
160
140
120
100
80
60
40
20
0
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (Sec)

APPENDIX C

DATA & PLOTS

D:\Complete\01 March, 2010 Test 7, Girders Section 3, 100k plots.xls

D:\Complete\22 Feb, 2010 Test 1, Section 2 & 4, 20k plots.xls

D:\Complete\23 Feb, 2010 Test 2, Section 2 & 4, 90k plots.xls

D:\Complete\25 Feb, 2010 Test 3, Outer Section 3, 85k plots.xls

D:\Complete\25 Feb, 2010 Test 4, Outer Section 3, 100k Early Offload plots.xls

D:\Complete\26 Feb, 2010 Test 5, Outer Section 3, 100k plots.xls

D:\Complete\26 Feb, 2010 Test 6, Section 3, 100k plots.xls

INSTRUMENT LOCATION MEASUREMENT PICS

D:\Vanadium Gage Pictures\...